MASTER OF SCIENCE
IN
METEOROLOGY AND PHYSICAL OCEANOGRAPHY

IMPROVEMENT OF METOC ANALYSIS AND FORECAST VISUALIZATIONS

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Current METOC weather visualization tools do not allow warfighters, forecasters, and researchers to analyze and co-display environmental data over realistic topographic and bathymetric backgrounds. In this thesis the Joint METOC Global Image Interface is developed and provides decisionmakers and geoscientists with an intuitive tool for interactively viewing, overlaying, and outputting the full suite of FNMOC distributed environmental data over realistic and accurate terrain, coastlines, hydrography, and locally obtained imagery. Full integration into the Joint METOC Viewer ensures minimal training time for operational use and geodata distribution is accomplished on the program distribution CD or over the web. The evolution of traditional METOC visualization, and the characteristics of the geodatabases are discussed and recommendations for further work in this area are presented. New capabilities are illustrated using real world examples drawn from diverse application areas.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation, Computing and Software

KEYWORDS: Visualization, Meteorology and Oceanography, METOC, Forecasting, Analysis

ERROR ANALYSIS OF REAL-TIME REMOTELY SENSED MICROWAVE SEA-ICE MOTIONS IN THE WESTERN ARCTIC OCEAN

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An algorithm used to composite SSM/I 85.5 GHz imagery and derive sea ice motion was adapted for operational testing at Fleet Numerical Meteorology and Oceanography Command (FNMOC). A feature tracking technique was applied to a 6-month period, with data provided by FNMOC and the Naval Research Laboratory (NRL). Ice motions are detectable using the SSM/I motion algorithm, and fields of SSM/I motion vectors are qualitatively consistent with coincident fields of in situ buoy motion vectors. Accuracy of the SSM/I motion vectors relative to buoy motion vectors increase significantly with buoy speed. No correlation between SSM/I and buoy motion vectors is observed for speeds below 3 cm/s and correlation increases significantly above 5 cm/s. The results are very sensitive to compositing techniques used to combine SSM/I passes into a single sea ice representation. FNMOC data was composited using a “drop-in-

the-bucket" technique while NRL data was composited by a bi-linear interpolation technique. Significantly poorer results were found with FNMOC composited data.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Microwave, Remote Sensing, Arctic Sea Ice, Sea Ice Motion

LUTION OF BEDFORMS ON THE INNER-SHELF

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Observations of the temporal evolution of the wave-formed ripples are analyzed in terms of geometric properties, migration rate, and forcing by wave and current velocities. Three weeks of bedform observations were obtained using underwater video of a sheet of laser light projected on the bed at the Monterey Bay Inner Shelf Observatory in thirteen-meter depth water. The bed consists of fine sand (mean grain size 0.12mm). Low to moderate narrow-band swell waves occurred during the observation period. Ripple geometry consisted of orbital and suborbital vortex wave ripples, and relic ripples left after larger wave events. The bedforms generally changed size and shape when the grain roughness Shields parameter exceeded a critical value of 0.04 with the exception of the last event bringing into question the appropriate value of 2_{crit} in nature. Ripple migration was offshore at rates of 2-10 cm/day during active sediment transport events. Skewness of velocities (low and high passed) were calculated to explain offshore ripple migration, but showed no preferred direction. Mean currents were weak and also showed no preferred direction. Significant positive (offshore) correlation was obtained between the short-wave envelope and infragravity waves indicating wave-group forced bound long waves (surf beat) combined with stirring by the short waves might explain the offshore sediment transport and ripple migration.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Ripples, Sediment Transport, Shields Parameter, Bound Long Waves

HEAT FLUXES ASSOCIATED WITH INTRUSIONS DURING THE SHEBA ICE STATION DRIFT

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A yearlong set of temperature and salinity profiles from the Surface Heat Budget of the Arctic (SHEBA) is analyzed to identify intrusions from the mixed layer to a depth of 150 meters. Ensemble averaged temperature and salinity profiles, spectral analysis of the vertical thermal structure, and bathymetry are used to divide the SHEBA ice station track into four regions: Beaufort Sea; Northwind Rise and break; Chukchi Plateau and break; Mendelev Abyssal Plain. Average vertical gradients of temperature and salinity over intrusive features are used to calculate Turner angles and molecular heat fluxes. Bering Sea Summer Water dominates the structure in the temperature and salinity profiles of the Northwind Rise region, with a maximum temperature intrusion of 2.2°C. Cold intrusions penetrate the upper halocline in the Chukchi Plateau region. The width of the distribution of Turner angle in the vertical profiles is indicative of the degree of the interleaved structure. Mesoscale features and associated internal wave activity accompany highly variable vertical structure over the Northwind Rise and Chukchi Plateau regions. The role of intrusions in lateral mixing and lateral heat transport is discussed in context of the observed regional differences in water mass properties.

DoD KEY TECHNOLOGY AREA: Battlespace Environments, Modeling and Simulation

KEYWORDS: SHEBA, Intrusions, Heat Fluxes, Halocline, Double-diffusion, Turner Angle

FORECASTING MESOSCALE WINDS ON COMPLEX TERRAIN USING A SIMPLE DIAGNOSTIC MODEL

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The use of mesoscale models to provide an accurate representation of what the atmosphere is likely to do in the near future is one of the tools forecasters utilize to predict atmospheric variables. Because of the large amount of time and computer resources necessary to provide detailed forecasts on the mesoscale, this study looked at forecasting winds utilizing a simple diagnostic model and compared its results to a full physics model. Winds from the Fifth Generation Mesoscale Model (MM5), were run at fairly coarse grid spacings of 81, 27, and 9 kilometers and at a finer grid spacing of three kilometers. The MM5 9 kilometer results were input into the Winds On Critical Streamline Surfaces (WOCSS) model, which is a scaled down physics model designed to adjust winds to fine scale topography. A comparison of how the WOCSS model winds compared against each of the MM5 grid spacings was evaluated for an event during the period 4-7 August 1997 in the SOCAL bight region to determine if the results of the scaled down physics model were comparable to the full physics model. This experiment showed encouraging results for forecasting fine scale winds on complex topography using the simple diagnostic model.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Environmental Quality, Modeling and Simulation

KEYWORDS: Mesoscale Modeling, Wind Forecasting, Wind Simulation

AUTOMATED METEOROLOGICAL AND OCEANOGRAPHIC DATA COLLECTION AND DISTRIBUTION IN SUPPORT OF C4I, WEAPONS, AND REMOTE SENSING SYSTEMS

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On-scene characterization of the battlespace environment is critical toward providing the warfighter with an effective understanding of the environment and its impact on weapon systems and sensors and requires the rapid acquisition and dissemination of on-scene meteorological and oceanographic (METOC) measurements. The current practice of manually observing and recording METOC data is labor intensive, outdated, and no longer capable of satisfying the requirements for higher temporal and spatial observations.

This study reviews the current methodology to characterize the battlespace environment, summarizes relevant Navy needs, and describes the results of integrating a prototype small combatant integrated METOC system (SCIMS) developed by the Naval Postgraduate School, with a prototype data processing and distribution system (Weather Viewer) developed by SPAWARSYSCEN San Diego.

At-sea demonstration included the acquisition, encoding, transmission and retrieval of real-time observations to/from shore based METOC data servers at Fleet Numerical Meteorology and Oceanography Center via commercial telephone access to the Internet. The demonstration further served as the basis for development of a PC based prototype Shipboard METOC Archive and ReporTs system called SMART Log.

The study concludes with particular recommendations for updating and improving the system of environmental data collection, processing, utilization, and archival.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Battlespace Environments, Command, Control and Communications, Computing and Software, Electronic Warfare, Environmental Quality, Sensors, Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation

KEYWORDS: Internet, Metcast, Meteorology, METOC, Moriah, Oceanography, SCIMS, Seawasp

SUPPRESSION OF MARINE STRATOCUMULUS CLOUDS DUE TO REDUCED CLOUD CONDENSATION NUCLEI

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Cloud researchers have documented a variety of processes at work in the formation and dissipation of clouds in the marine boundary layer (MBL). Cloud rifts occasionally mark a distinct exception to the continuity and broad coverage more commonly observed with these clouds. A possible explanation for the presence of large features of broken cloudiness embedded in stratocumulus is the removal of CCN by nucleation scavenging and drizzle.

A cloud rift feature embedded in marine stratocumulus was observed in satellite imagery on July 16, 1999. A CIRPAS Twin Otter aircraft flew repeated crossings of the rift boundary while completing a comprehensive survey of the area. A comparison of microphysics and thermodynamics on opposite sides of the rift boundary indicate that these rifts form where low aerosol concentrations enhance drizzle production. Marine boundary layer aerosol concentrations in the rift were only 1/6 that observed below the background stratocumulus. Cloud droplets in rift clouds were 35 microns larger than droplets in stratocumulus and exhibited a broader size distribution. Drizzle observations were strongly correlated with the rift and calculations support a drizzle hypothesis for rift formation and maintenance. Aerosol losses can be accounted for in drizzle droplets and the disruption of the cloud layer evolves in a manner described by Ackerman (1993).

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Marine Clouds, Precipitation, Aerosol, Marine Atmospheric Boundary Layer, Environmental Effects

VALIDATION OF THE MINE IMPACT BURIAL MODEL USING EXPERIMENTAL DATA

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The Navy's Impact Burial Prediction Model creates a two-dimensional time history of a bottom mine as it falls through air, water, and sediment. The output of the model is the predicted burial depth of the mine in the sediment in meters, as well as height, area and volume protruding. Model input consists of environmental parameters and mine characteristics, as well as parameters describing the mine's release. The model user seldom knows many of these parameters, and those that are known may be of questionable precision. In order to run a realistic validation of the model, an experiment was conducted using a simulated mine and carefully controlled observations while simultaneously taking gravity cores. The model was then run and calculated results were compared to observed.

Final results showed the model tended to over predict burial depth by an order of magnitude due to a lack of sensitivity to hydrodynamic effects in the water column.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Mines, Sediment, Hydrodynamics, Mine Warfare

AN ANALYSIS OF SHORT TERM MESOSCALE FORECASTS IN THE LOS ANGELES BASIN USING SOUTHERN COAST OZONE STUDY 1997 DATA

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Mesoscale models are important, useful tools for analyzing and forecasting small-scale atmospheric phenomena. Ideally, finer grid-point resolution should make a model more likely to capture realistic small-scale structure. Because these models work to resolve phenomena that exist on very fine spatial- and time-scales, they are subject to high variability. Accurate initialization of mesoscale models is crucial to skillful short-term forecasting.

This study exercises four different initialization and model physics experiments of four nested MM5 forecast domains and examines their respective short-term (f03, f06, f09, f12) forecasts. The exceptionally rich meteorological data set taken from the Southern Coast Ozone Study of 1997 (SCOS97) provides the basis for our model verification.

It is shown that 3km and 9k resolutions produce better forecasts than the 27km resolution model, however, differences between the 3km and 9km resolution forecasts are essentially insignificant. It is also shown that different model initializations and physics schemes have an insignificant impact on improving the absolute accuracy of the numerical forecasts produced by a non-hydrostatic mesoscale model.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Environmental Quality, Modeling and Simulation

KEYWORDS: Mesoscale Models, Numerical Forecasts

THE ROLE OF THE PLANETARY BETA EFFECT ON CURRENTS AND EDDIES IN THE LEEUWIN CURRENT SYSTEM

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To investigate the effect of the role played by planetary beta in the generation and maintenance of the Leeuwin Current System (LCS), several numerical experiments are conducted with varying Coriolis parameterizations (f-plane or β-plane). The seasonal effects of thermal gradients, wind forcing and North West Shelf (NWS) waters are also systematically explored in the numerical experiments. Additionally, the generation mechanisms for undercurrents along both the western and southern coasts of Australia are investigated.

Although surface currents, undercurrents, and mesoscale activity are present in both the f-plane and β-plane experiments, those run on a β-plane show a more realistic depiction of these features due to the significant role played by the planetary beta effect in the LCS. The combination of thermal forcing, wind forcing, and NWS waters were found to be essential to maintain the highly seasonally varying LCS. Alongshore temperature gradients, which are generated at deeper levels by the strong flow of the Leeuwin Current, are sufficient to establish and maintain an equatorward (westward) undercurrent along western (southern) Australia.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Primitive Equation Model, Leeuwin Current System, Currents, Meanders, Eddies, Filaments