MASTER OF SCIENCE
IN
METEOROLOGY AND PHYSICAL OCEANOGRAPHY

EL NINO AND LA NINA EFFECTS ON TROPICAL CYCLONES: THE MECHANISMS

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The effects that El Niño and La Niña events exert on western North Pacific tropical cyclones, and the physical mechanisms involved were examined using best track data from the Joint Typhoon Warning Center and NCEP reanalysis data. During El Niño and La Niña events, equatorial heating anomalies induce anomalous tropical and extratropical atmospheric wave trains which alter circulation, vertical shear, and steering flow.

The shear changes cause tropical cyclones to form farther south and east (north and west) than normal during El Niño (La Niña) events. These formation differences lead to longer (shorter) tracks and stronger (weaker) tropical cyclones during El Niño (La Niña) events. Late in the tropical cyclone season, the anomalous extratropical waves alter the subtropical ridge and steering flow to favor recurving (straight running) tropical cyclones during El Niño (La Niña). These track differences lead to a much higher number of landfalling tropical cyclones in southeast Asia during La Niña events.

A preliminary study of the North Atlantic shows that there are more, and stronger, tropical cyclones during La Niña than El Niño. This is the result of extratropical Rossby wave trains that originate in the east Asia and extend into the North Atlantic. There they alter the vertical shear, so that La Niña favor more formations in the tropical Atlantic, where other conditions are favorable for the development of strong tropical cyclones.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Environmental Quality, Sensors, Modeling and Simulation, Other (Meteorology, Oceanography)

KEYWORDS: El Niño, La Niña, Tropical Cyclones, Hurricanes, Typhoons, Climate, Pacific, Aatlantic

A STUDY ON THE TIMING OF THE SOUTHWEST MONSOON ONSET IN THE SOUTH CHINA SEA

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The boreal summer in the South China Sea is preceded by a spring to summer transition period that coincides with the end of the dry season and start of the rainy season throughout Southeast Asia. The rainy season is identified with the arrival of the Southwest Monsoon. The monsoon onset in the northern portion

of the South China Sea normally occurs during May of each year but can range from early May to early June. This work studied the differences of the large scale flow for different timing categories of onset, and if differences could be noted during onset with the presence of tropical cyclones. NCEP/NCAR reanalyses data and NOAA AVHRR GPI data from OLR fields were used for May and June for the years 1979 – 1999. Timing of onset appears to be determined by the arrival of the Mei-Yu front. When tropical cyclones are present, a vortex tends to occur in the Bay of Bengal.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Monsoon Onset, Southwest Monsoon

SAND BED ROUGHNESS IN THE NEARSHORE, COAST 3D EXPERIMENT, EGMOND AAN ZEE, THE NETHERLANDS

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Sand bed roughness was measured in the nearshore during a variety of hydrodynamic conditions using an array of seven 1 MHZ sonar altimeters mounted on the WESP (an amphibious vehicle used for measuring large-scale bathymetry) during the COAST 3D Experiment 1998, at Egmond aan Zee, The Netherlands. Corollary waves were modeled using the Thornton and Guza (1983) wave transformation model. Wave height and current measurements were made in the surf zone using pressure sensors and electromagnetic current meters, and offshore wave heights were measured using an advectional wave-rider buoy. Measurements of sand bed roughness showed patterns similar to those observed by Clifton et al. (1971), but are highly variable both spatially and temporally with dependence on large scale morphology and wave and current conditions. Mobility number (Ψ) calculated from the modeled wave field and also from measured currents revealed that roughness is a function of Ψ. Roughness was observed to be highly variable at low Ψ (< 100) calculated from the modeled wave heights. As Ψ increased (100-150), roughness decreased gradually, but was still highly variable. As Ψ reached values greater than 150, roughness was restricted to the lowest observed values (< 3 cm) implying planar beds under sheet flow conditions.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Sand Bed Roughness, Megaripples, Ripples, Sediment Transport, Nearshore Processes, Morphology

LARGE EDDY SIMULATION OF INTERACTIONS BETWEEN FREE CONVECTION, WIND DRIVEN CURRENTS, AND BAROCLINICITY IN THE LABRADOR SEA DEEP MIXED LAYERS

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Understanding the dynamics of deep convection leading to the formation of deep water is important not only for studying the small-scale generation regions, but also for studying the global-scale thermohaline circulation. Large Eddy Simulation (LES) is used to model deep convection with an imposed mean horizontal density gradient of two different strengths and wind forcing from various directions, with strong surface cooling representative of the Labrador Sea. Results from these different cases are compared and analyzed to understand the effects of horizontal density gradients and wind direction on turbulence statistics

for deep convection. Both the strength of horizontal density gradients and wind direction relative to the gradient affect mixed layer scalar variances, turbulent vertical fluxes, Vertical Turbulent Kinetic Energy (VTKE), and stability during deep convection.

Wind direction dominates over gradient strength in determining vertical flux magnitude with larger variation in strong gradient cases. Levels of VTKE are more dependent on gradient strength, with weaker gradients producing higher values of VTKE than stronger gradients regardless of wind direction. Wind direction does alter VTKE levels in the same manner as it alters vertical flux levels. The presence of a horizontal gradient is a stabilizing factor in areas of strong surface cooling.

DoD KEY TECHNOLOGY AREA: Other (Meteorology and Oceanography)

KEYWORDS: Large Eddy Simulation, Deep Convection, Labrador Sea, Baroclinicity

UNDERSTANDING MESOSCALE ERROR GROWTH AND PREDICTABILITY

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Technological advances have made atmospheric mesoscale modeling at very fine resolutions readily available to a great number of organizations. Though initial operational results show some skill with respect to synoptic scale forecasts, many of the problems associated with mesoscale error growth and predictability have been ignored. Understanding mesoscale error is critical to accurately interpreting mesoscale model results and output from tactical decision aids (TDAs).

This study examines mesoscale error growth and predictability through controlled numerical model experiments. A known “true” atmosphere is created through the use of the US Navy’s Coupled Oceanographic/Atmospheric Mesoscale Prediction System (COAMPS). Virtual observations are randomly sampled from this atmosphere to provide data for ingest into forecasts using the NCAR/Penn State MM5 mesoscale model. Forecast results for ten cases are compared against the “true” atmospheric solution and error statistics are calculated for wind speed and geopotential height fields. Results show how error growth and predictability are affected by different variables such as boundary conditions, weather regime, sample size and sample distribution. A scale separation of error is also performed in order to assess the impact of synoptic scale error on mesoscale error.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Mesoscale Modeling, Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS), Error Growth, Predictability

ESTIMATION OF STRATOCUMULUS-TOPPED BOUNDARY LAYER DEPTH USING SEA SURFACE AND REMOTELY SENSED CLOUD-TOP TEMPERATURES

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The depth of the marine atmospheric boundary layer (MABL) is an important parameter for both scientific and operational meteorological applications. The depth of the marine boundary layer has a significant influence on the atmospheric dynamics in the coastal zone. Knowledge of the depth of stratocumulus-topped boundary layers (STBLs) will enable coastal operations to more accurately anticipate weather, and electromagnetic propagation conditions. This study develops a satellite remote sensing technique for determining the height of MABLs topped with stratocumulus clouds.

Validation of the technique using coastal rawinsonde dataset from the Monterey Area Ship Track (MAST) experiment revealed that an assumption of 41% cloud with a moist lapse rate equal to –7.0°C/km had the best overall fit to the data. However, for shallow boundary layers with depths below 400m the most accurate assumption was 75% cloud with a moist lapse rate equal to –6.5°C/km. The application of this technique to sounding data returned an overall BL depth accuracy of 50m while the satellite application returned an overall accuracy of 65m. A sensitivity analysis of both surface and cloud-top temperature revealed that a 1/2°C change in either temperature resulted in an error of 60-70m in boundary layer depth.

DoD KEY TECHNOLOGY AREA: Other (Meteorology, Oceanography)

KEYWORDS: Boundary Layer Depth, Remote Sensing, Stratocumulus, AVHRR

OPTIMIZATION OF MAS AND MODIS POLAR OCEAN CLOUD MASK

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With the reduction of funding for sea ice reconnaissance flights, the National/Naval Ice Center needs to capitalize on the improvements in satellite technology. Imaging sensors such as AVHRR, DMSP/OLS, SSM/I and RADARSAT are used to detect the presence of sea ice, but with the exception of SSM/I and RADARSAT, clouds are a major obstacle to viewing the surface. With NASA's development of the Moderate-resolution Imaging Spectroradiometer (MODIS) and MODIS Airborne Simulator (MAS), there is finally a sensor capable of using multi-spectral techniques to detect the presence of clouds.

A group at the Space Science and Engineering Center (SSEC), University of Wisconsin – Madison lead by Dr. Steve Ackerman has developed a cloud mask for MAS/MODIS. The technique determines a level of confidence that a given pixel is clear based on a series of multi-spectral tests. By combining the confidence level from all tests, it is possible to detect the presence of clouds at different altitudes in the atmosphere. Threshold optimizations are described in this thesis for the $T_B(11\mu m)$ and $T_B(3.9\mu m)$ - $T_B(11\mu m)$ tests from Ackerman et al. (1997). In addition, the $T_B(11\mu m)$ - $T_B(12\mu m)$ test is removed. These modifications are based on daytime analysis of several MAS cases and a limited number of MODIS cases.

Subjective analysis shows the modifications greatly improve the detection of clouds over cold polar oceans where sub-pixel ice may be present or water temperatures might falsely indicate clouds. The number of *Cloudy* pixels (▶0.66 clear confidence level) for a given scene was increased 12.1% on average for MAS cases. The NPS cloud mask also classified two times more *Probably Clear* and *Undecided* pixels than the original mask due to greater sensitivity to thin, small clouds.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors, Other (Remote Sensing)

KEYWORDS: Moderate Resolution Imaging Spectroradiometer (MODIS), MODIS Airborne Simulator, Terra Satellite, Cloud Mask, Sea Ice

THE ROLE OF THE PLANETARY BETA EFFECT ON CURRENTS AND MEDDIES IN THE NORTHERN CANARY CURRENT SYSTEM

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To investigate the role of planetary beta on classical as well as unique features in the northern Canary Current System (NCCS), four numerical experiments are conducted with varying Coriolis parameterizations (*f*-plane or ∃-plane). The first two experiments use a closed boundary and annual salinity forcing for the Mediterranean Outflow (MO). The latter two experiments use an open Mediterranean Sea at the Strait of Gibraltar and seasonal forcing for MO to permit a more accurate investigation of the role of the beta effect on subsurface spreading of MO and Meddies. All four experiments use seasonal climatological winds and seasonal thermohaline gradients along the western boundary to force the model. Experiments run on a ∃-plane (Experiments 2 and 4) accurately portray classical eastern boundary current (EBC) mesoscale features. In addition, these experiments depict unique NCCS features associated with a large embayment (the Gulf of Cadiz), poleward spreading of MO, and the generation of Meddies. Experiments run on an *f*-plane (Experiments 1 and 3) show the unrealistic dominance of a continuously strengthening equatorward jet that inhibits development of classical EBC and unique NCCS features. The complex upper layer and subsurface flow regimes of Experiment 4 most realistically portray currents, mesoscale features and Meddies similar to NCCS observations.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Primitive Equation Model, Northern Canary Current System, Currents, Meanders, Eddies, Meddies, Filaments, Mediterranean Outflow

SWELL TRANSFORMATION ACROSS THE CONTINENTAL SHELF

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A preliminary analysis of swell decay across the continental shelf was conducted using data from the SHOaling Waves EXperiment (SHOWEX). Six Datawell Directional Waverider buoys were deployed along a cross-shelf transect, offshore of Duck, North Carolina during an active hurricane season in the fall of 1999. Estimates of the frequency spectrum, $E(f)$, mean propagation direction, $\theta_{mean}(f)$, and directional spread, $\sigma_\theta(f)$, were obtained from the auto-, co- and quadrature spectra of the horizontal and vertical orbital displacements measured by the buoys. Twelve cases were analyzed including eight cases dominated by remotely generated long period swells arriving from various directions. The last four cases were characterized by active wave generation by strong winds on the continental shelf, including the passages of Hurricanes Floyd and Irene. Comparisons of significant wave heights of swell observed at all buoys show a consistent strong decay across the shelf supporting the major role of bottom friction in swell transformation. A decline in wave heights near the coast was also observed during the passage of hurricanes, due to limited fetch and enhanced bottom friction in shallow water. Estimates of θ_{mean} show the expected refraction of waves to shore-normal directions on the inner shelf. Estimates of σ_θ generally do not vary much across the shelf. However, a sharp increase of σ_θ across the inner shelf was observed for directionally narrow swells from Hurricane Gert, possibly due to wave scattering from bottom irregularities. In all cases, σ_θ was at a minimum at the spectral peak frequency.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Swell Transformation, Continental Shelf, Directional Wave Spectra, Wave Dissipation, Wave Buoy, Refraction