DEPARTMENT OF METEOROLOGY

Thesis Abstracts

OBSERVATION ADJOINT SENSITIVITY AND THE ADAPTIVE OBSERVATION-TARGETING PROBLEM

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This research introduces the adjoint of the data assimilation system, which together with the classical adjoint sensitivity problem, represents the two fundamental components of the complete forecast adjoint sensitivity problem. This adjoint of the data assimilation system is then used to investigate the sensitivity of the forecast aspect to the observations and background for idealized analysis problems, and finally a real-data case using the NAVDAS adjoint for a situation with unusually large 72-h forecast errors over the western United States during February 1999.

The observation sensitivity is largest when the observations are relatively isolated, assumed to be more accurate than the background, and the analysis sensitivity gradients are large in amplitude and have a spatial scale similar to the background error covariances. The observation sensitivity is considerably weaker for small-scale analysis sensitivity gradients. The large observation sensitivities suggest that adaptive observations near large-scale analysis sensitivity gradients have a greater potential to change the forecast aspect than observations near small-scale analysis sensitivity gradients. Therefore, targeting decisions based on the adjoint of the data assimilation system may be significantly different from targeting decisions based solely on the analysis sensitivity gradients. These results emphasize the importance of accounting for the data assimilation procedures in the adaptive observation-targeting problem.

DoD KEY TECHNOLOGY AREA: Battlespace Environments

KEYWORDS: Observation Sensitivity, Observation Adjoint Sensitivity, Adaptive Observations, Observation Targeting, Data Assimilation, Adjoint Methods

PARAMETERIZING SURFACE FLUXES IN THE ARCTIC

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There is a need for computationally efficient methods to determine surface radiation in the Arctic based on surface parameters such as cloud presence, sun angle, temperature and other easily measured variables. This study uses data from the SHEBA project to verify simple radiation parameterizations and to compare with other locations. Skies during SHEBA were usually either totally clear or totally overcast, with low clouds predominating, especially in the non-winter seasons. This resulted in large changes in radiation every time the cloud coverage changed.

There was a large range in the skill of the parametric equations. The most accurate equations had average total errors of 9 Wm^{-2}, 14 Wm^{-2}, 22 Wm^{-2} and 59 Wm^{-2} for downwelling longwave in clear skies, cloudy skies, shortwave clear and cloudy skies respectively. Compared to the Weddell Sea (Antarctic) the average downward longwave radiation was greater for all sky conditions. Shortwave values were comparable to the Weddell Sea, although there was large variability.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: SHEBA, Surface Radiation, Arctic

THE ROLE OF WEATHER IN CLASS A NAVAL AVIATION MISHAPS

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Two hundred-thirty five Class A Navy and Marine (Naval) aviation mishaps involving aircrew error between FY90 and FY98 are analyzed for the possibility of being weather related. In addition to determining the overall role of weather, weather related mishaps are compared to aircraft category, mishap characteristic, the Naval Safety Center Human Factors (HFACS) taxonomy, and flight phase. In addition, weather related mishap trends have been analyzed. Results show 19% of mishaps involving aircrew error are weather related with helicopter category and controlled flight into terrain (CFIT) mishap characteristics having the largest percent of weather related mishaps for their respective groupings. Visibility related weather elements account for over half of all weather related mishaps, and nearly two-thirds of all weather related mishaps were judged to be preventable with a perfect weather forecast believed by the aircrew. These and other findings are presented to develop intervention strategies for reducing the number of weather related flight mishaps (FMs) per year.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Human Systems Interface, Other (Accident Analysis, Aviation Weather)

KEYWORDS: Naval Aircraft Mishaps, Human Factors, Human Error, Accident Classification, Accident Analysis, Aviation Weather

NUMERICAL PREDICTION OF MARINE FOG USING THE COUPLED OCEAN/ATMOSPHERE MESOSCALE PREDICTION SYSTEM (COAMPS)

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The U.S. Navy's requirement for a computer prediction system for marine fog and stratus dates back to the 1970s when meteorological models were being introduced to the fleet. The Naval Research Laboratory's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) is a leap forward in the Navy's numerical modeling ability but it still does not show great skill in fog forecasting. COAMPS has been "tuned," or adjusted for certain constants and parameterizations, so that it has the minimum error for the maximum area. This tuning is a common practice for all numerical models. The objective of this thesis is to determine if changes can be made to the existing COAMPS code based on reasonable physical experiments for a specific location to help solve the numerical fog forecasting problem. The effectiveness of these experiments was first measured by comparing a modeled cloud edge to satellite imagery of Monterey, California taken during a week in August 2000 under a variety of foggy conditions. Comparisons were also made with observations taken from an aircraft, land stations and a vertical profiler. The experiments, specifically those regarding changes to the autoconversion and turbulent kinetic energy schemes, showed that while a perfect solution has not been found, it is possible to modify the model physics codes and optimize its performance in a specific region.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Mesoscale Modeling, Model Verification, COAMPS, Fog, Stratus, Forecasting

EL NINO AND LA NINA EVENTS AND NORTH ATLANTIC TROPICAL CYCLONES

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The impacts of El Niño (EN) and La Niña (LN) events on North Atlantic tropical cyclones (TCs) were examined, and the physical mechanisms that produce these impacts. Composites of best-track data were constructed from the National Hurricane Center and reanalysis data from the National Centers for Environmental Prediction based on ten EN and ten LN events that occurred during 1970-1999. We analyzed the differences in the composite TC numbers, formation sites, and tracks during EN and LN events for several periods within the North Atlantic TC season (June-November).

The largest differences occurred in the middle (July-September) and late (September-November) portions of the TC season. Throughout almost all of the season, there were more TC formations during LN events than during EN events, especially in the tropical North Atlantic (about 10-20oN). However, in the late season, there were more formations during EN events in the subtropical North Atlantic (about 20-30oN). The formation site differences appear to have been mainly the result of lower vertical shear in the tropics during LN events, and lower vertical shear in the subtropics during EN events. The vertical shear differences over the tropical North Atlantic were mainly the result of anomalies in upper tropospheric heights and the tropical easterly jet associated with variations of the Asian summer monsoon. The vertical shear differences over the subtropical North Atlantic were mainly the result of an extratropical anomalous wave train extending from the western North Pacific to the North Atlantic.

The differences in formation sites appear to have led to TCs with longer tracks, longer residence times within a tropical environment, and greater intensities during LN events. There were a larger (smaller) number of TCs making landfall in the Gulf of Mexico and eastern U.S. during LN (EN) events during the late season. These differences appear to have been the result of: (1) more (fewer) low latitude formations during LN (EN) events; and (2) steering flows associated with the anomalous extratropical wave train that tended to guide TCs into (away from) the Gulf of Mexico and the east coast of the U.S. during LN (EN) events.

DoD KEY TECHNOLOGY AREA: Other (Environmental Modeling, Climate Monitoring)

KEYWORDS: El Niño, La Niña, North Atlantic Tropical Cyclones, Tropical Easterly Jet, Teleconnections, Wave Trains

CLASSIFICATION OF SUMMERTIME WEST COAST FOG AND STRATUS EVENTS AND THE DEVELOPMENT OF FOG AND STRATUS FORECAST TECHNIQUES

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The fog and stratus that frequently plagues the West Coast in the summer months is responsible for a variety of impacts on everyday life, the greatest being on aviation. Many flight delays and cancellations that are experienced around the Pacific Rim are attributed to the development and evolution of the fog and stratus on the U.S. West Coast. This thesis studies the evolution of the fog and stratus events during the summer of 2000 through the use of geostationary, GOES-10, visual satellite imagery to develop a classification scheme. The synoptic-scale weather patterns as well as the mesoscale coastal regime were then associated with a type of stratus evolution. The Navy's mesoscale model, coupled ocean/atmosphere mesoscale prediction system (COAMPS), provided detailed simulation of 11 events to highlight the boundary layer evolution and its relationship to fog and stratus evolution. The fog and stratus classification scheme produced several consistent synoptic and mesoscale signals associated with stratus evolution. These

relationships provide some forecasting techniques that should aid forecasters with predicting the evolution of fog and status events.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Visual Satellite Imagery, COAMPS, Synoptic-Scale Weather Patterns

TROPICAL CYCLONE AND MID-LATITUDE CHARACTERISTICS AND PHYSICAL MECHANISMS CONTRIBUTING TO EXTRATROPICAL TRANSITION IN THE WESTERN NORTH PACIFIC

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This study of extratropical transition (ET) of tropical cyclones (TCs) in the western North Pacific examines 30 cases during 1 June through 31 October 1994-98 using Navy analyses, plus geostationary satellite visible, infrared, water vapor, and microwave imagery. Based on the similarity of all 30 ET cases in satellite imagery, a three-dimensional conceptual model of the transformation stage of ET is proposed to describe how these ET cases evolve into an incipient, baroclinic cyclone. A climatology of ET during the period studied is presented, and three levels of re-intensification (little, moderate, and deep) are defined based on storm intensity at the end of ET. The re-intensification stage in nine cases is studied via Navy Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS) control forecasts, simulations with the initial TC vortex removed, and simulations in which the initial TC vortex is displaced. These COAMPS simulations demonstrate that deep or moderate re-intensification depends on phasing of the poleward translating TC remnants with a critical region in which cyclogenesis is favored in the mid-latitude circulation. The mid-latitude circulation and TC contributions to the re-intensification stage are identified via superposition with the critical region and modification of its location and diagnostic values, respectively, and the combination of these contributions determines the final storm intensity at the end of ET.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Battlespace Environments, Command, Control, and Communications, Electronic, Electronic Warfare, Sensors, Modeling and Simulation, Other (Meteorological Support and Tactical Decision Aids)

KEYWORDS: Extratropical Transition of Tropical Cyclones, Transformation Stage, Re-intensification Stage, Critical Region, Petterssen Type-B Extratropical Cyclogenesis, Mid-latitude Circulation Contributions to Re-Intensification, Tropical Cyclone Contributions to Re-Intensification

A FINE RESOLUTION MODEL OF THE COASTAL EASTERN BOUNDARY CURRENT SYSTEMS OFF IBERIA AND MOROCCO

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To investigate the role of wind forcing, bottom topography and thermohaline gradients on classical as well as unique features in the northern Canary Current system (NCCS), four experiments are conducted with a sigma coordinate primitive equation model. The first experiment, which investigates the pressure gradient force error, shows that velocity errors inherent in three dimensional sigma coordinate models can be successfully reduced from ~1 m/s to less than 0.5 cm/s in the NCCS. The second experiment, which investigates the effect of annual wind forcing on a flat bottom, accurately portrays classical eastern

boundary current features as well as unique NCCS features associated with a large embayment (i.e., the Gulf of Cadiz), poleward spreading of Mediterranean Outflow, and the generation of Meddies. Theadditional effect of bottom topography in Experiment 3 shows that topography plays important roles in intensifying and trapping the equatorward current near the coast, in weakening the subsurface poleward current and in intensifying eddies off the capes of Iberia. The use of full instead of horizontally averaged thermohaline gradients in Experiment 4 highlights the development of the Iberian Current off the Portugal west coast, a feature not seen in the previous experiments. This shows that thermohaline gradients play an important role for the formation of the Iberian Current.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Primitive Equation Model, Northern Canary Current System, Currents, Meanders, Eddies, Meddies, Filaments, POM, Sigma Coordinate

INVESTIGATION OF THE 25 JANUARY 2000 EAST COAST CYCLOGENESIS

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On 25 January 2000, a rapidly developing cyclone tracked up the East Coast of the United States. Along with this system, 12 to 18 inches of snow fell on major cities from North Carolina to Washington DC. This snowstorm deserves special consideration because of the poor numerical and human forecasts it received.

The goal of this work is to analyze the performance of the Navy models, NOGAPS and COAMPS (West Atlantic) with the 25 January cyclogenesis event. Deficiencies with the model analyses and forecasts are identified and a diagnosis of critical model fields that led to these deficiencies is completed. Preliminary investigation of analyses and NOGAPS forecast runs with the new variational data assimilation system, NAVDAS, concludes the research.

The results of the research reveal that NOGAPS poorly forecast storm tracks while COAMPS showed more success. Both NOGAPS and COAMPS produced deficient short range upper-level height forecasts and had difficulty analyzing two prominent jet streaks. NOGAPS was not able to adequately analyze or forecast cold air damming and coastal frontogenesis, while COAMPS was more successful at resolving these features. COAMPS produced better precipitation forecasts than NOGAPS, but still showed deficiencies. Preliminary investigation of NOGAPS using NAVDAS shows promise.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Modeling and Simulation

KEYWORDS: Cyclogenesis, NOGAPS, COAMPS, NAVDAS

DIFFICULTIES IN IDENTIFYING AND EVALUATING SURFACE-BASED AND EVAPORATIVE DUCT IMPACTS

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RF /EO propagation depends on environmental variability and is critical to weapons system employment. This study is based on combined METOC and radio frequency (RF) loss data collected off the east U.S. coast, Wallops Island, VA. Addressed are atmospheric measurement, propagation modeling, and interpretation errors and their impact on the ship's operations. Examined are the determination of the presence and character of surface-based and/or evaporative ducts, and the interpretation of the conditions using current generation TDAs. Questions raised are a) "How closely can we describe the propagation

conditions from surface combatants?" and, b) "Can the operator, who is neither a meteorologist nor a propagation expert, produce meaningful products for himself, independent of outside support?" Environment horizontal variability was a critical limiting factor in predicting observed RF losses with operational METOC measurements using an operational propagation model. In addition to surface~ mounted METOC sensors aboard operational ships, rocketsondes were necessary to describe those features that limited predictability of observed RF losses. The results address the assumption of reciprocity for modeling/analyses purposes with horizontal variation. A conclusion is that the weapons systems operators' training must include familiarization with environmental awareness and self-assessment to utilize and exploit combined METOC data and propagation model predictions.

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

KEYWORDS: LKB, Paulus, Bulk Parameterization, Rocketsonde, Flux Buoy, Wallops Island, AREPS, RF Propagation, SEA W ASP, MORIAH, Refractivity, RF Propagation