THE EFFECT OF USING AWIPS LAPS TO LOCALLY INITIALIZE THE WORKSTATION ETA

Brian Etherton

Department of Geography and Earth Sciences
University of North Carolina at Charlotte
Charlotte, North Carolina

Pablo Santos

NOAA/National Weather Service
Weather Forecast Office
Miami, Florida

Abstract

This study presents results from an experiment conducted to measure the impact of locally initializing an atmospheric computer model on the model's ability to predict precipitation. The study consisted of enhancing the Advanced Weather Interactive Processing System (AWIPS) Local Analysis and Prediction System (LAPS) diagnostic analyses by using local mesonets, and then using these to locally initialize a mesoscale model. The mesoscale model used in the study was the Workstation Eta (WsEta). The experiment ran from 4 August 2003 to 11 October 11 2003. In addition to measuring the impact of using LAPS to initialize the workstation Eta, the impact of using different physical configurations on the model's performance was studied as well. Results show that, in general, LAPS had little impact overall on the WsEta's ability to forecast precipitation except within the first 12 hours of the forecast by the early morning runs (06 UTC) during a light wind regime. Results also show that among the different physical configurations tested, the non-hydrostatic and higher resolution runs were the most skillful in their ability to forecast diurnally driven daytime convection across South Florida.

1. Introduction

In South Florida, mesoscale weather features (e.g., land/sea breezes, thermal troughs, outflow boundaries, etc.) have a significant impact on day-to-day weather forecasts as they frequently represent the primary forcing for convection, particularly during the summertime. The combination of mesoscale-driven circulations and proximity of the Gulf Stream necessitates the use of high resolution products and forecast tools in order to provide the detailed information necessary for improving local forecasts. The advent of the Local Analysis and Prediction System (LAPS) at the NOAA/National Weather Service (NWS) Weather Forecast Offices (WFO) has made it possible to ingest high resolution data sets. These data sets support the local high resolution analyses that better resolve some of these features.

This study examines the impact of initializing a numerical weather prediction model with high resolution data; in particular, the Advanced Weather Interactive Processing System (AWIPS) LAPS diagnostic analyses. The Workstation Eta (WsEta, see Section 2b) model was used as the predictive model for this study. In addition to evaluating the impact of the LAPS initialization on the WsEta, the impact of different model configurations (Table 2) on the model's performance was studied as well. Using precipitation as a metric, model performance for different configurations and different initial conditions was evaluated using grid based threat scores, bias scores, and probability of detection for different precipitation thresholds. In general, results illustrate that the non-hydrostatic and higher resolution model configurations show the highest threat scores and probability of detection, and the smallest biases when considering daytime diurnal convection across South Florida.

The experimental phase of the study ran from 4 August 2003 to 11 October 2003. This work is the result of a Cooperative Program for Operational Meteorology, Education, and Training (COMET) Partners Project between the NOAA/National Weather Service Weather Forecast Office (WFO) in Miami and the University of Miami (UM). (Available online at http://comet.ucar.edu/outreach/partnow.htm.)

2. Data

a. Local Analysis and Prediction System (LAPS)

LAPS became available to the WFO with the advent of AWIPS. As delivered in AWIPS, LAPS is a diagnostic tool only. It consists of high resolution three-dimensional analyses of the atmosphere using locally and centrally available meteorological observations. LAPS incorporates data from a wide variety of meteorological observation systems onto a high-resolution grid centered on a domain of the users choosing. Data from local networks of surface observing systems, Doppler radars, satellites, wind and temperature (RASS) profilers (404 and boundary-layer 915 MHz), as well as aircraft are incorporated

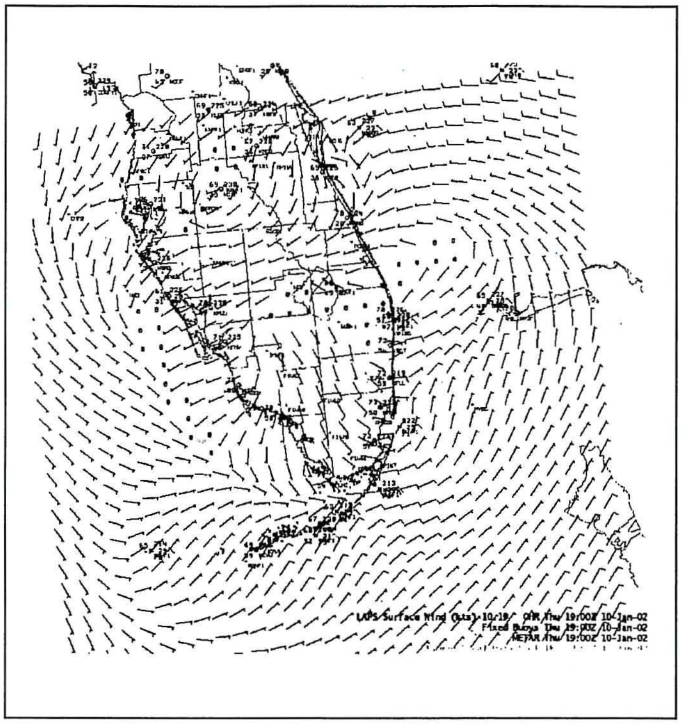

Fig. 1. Domain of WFO Miami LAPS analyses.

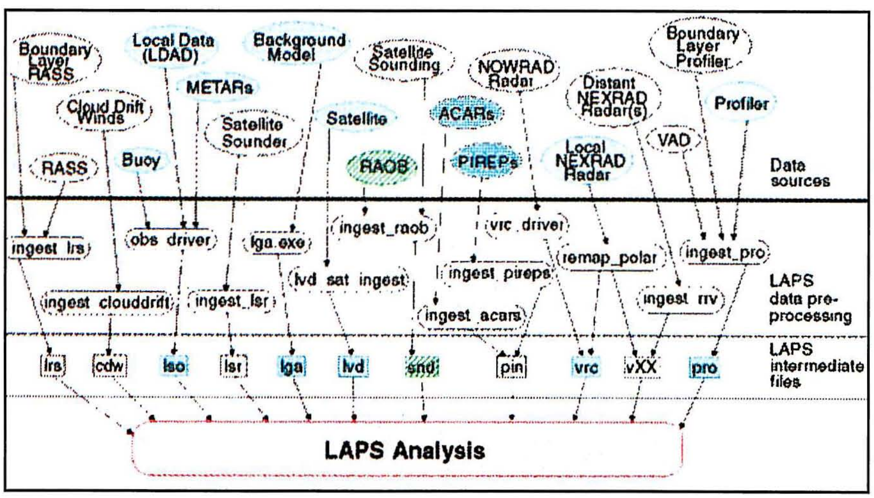

Fig. 2. Schematic of LAPS data sources. Although LAPS is capable of ingesting many different data streams, only those highlighted in blue and green are used in the operational LAPS analyses at a typical WFO running AWIPS Operational Build 3.

Table 1. Root Mean Square (RMS) errors for selected fields of the model background (AWIPS RUC 40 1 hour forecast) versus LAPS analyses with standard (Std) and standard plus non-standard (All) datasets for the experimental period. #Stns refers to the number of stations used to calculate the RMS across the LAPS domain.

Field	RUC (40)	LAPS Analysis		#Stns	
		Std	All	Std	All
T (F)	4.32	3.15	1.73	45	236
Td (F)	4.77	4.58	4.24	40	203
WS (kts)	2.66	2.50	2.13	45	240
MSLP (mb)	0.85	0.65	0.33	30	31

into the analyses (Albers 1995; Albers et al. 1996; Birkenheuer 1999; McGinley 2001; Schultz and Albers 2001). At the Miami WFO, the analyses during the experimental period were produced every hour in a three-dimensional grid covering a 600 km by 600 km area. The horizontal resolution of the hourly LAPS surface analyses produced at WFO Miami is 10 km with 39 vertical levels from 1000 mb to 50 mb at 25 mb intervals. The analysis domain centered on WFO Miami County Warning Area (CWA) is shown in Fig. 1. The background field for the analyses is obtained from the AWIPS RUC 40 km 1 hour forecast. Figure 2 represents a summary of all the data sources LAPS is capable of assimilating into its three dimensional analyses, as well as those data sets used in the AWIPS LAPS running at WFO Miami.

As it is evident in Fig. 2, not all data that LAPS is capable of ingesting is actually used operationally at the local WFO level. Despite the fact that LAPS is equipped with a Kalman filter (for quality control), as well as balance and cloud analysis diabatic packages, none of these were used in the WFO Miami AWIPS version during 2003 due to hardware limitations. However, in an attempt to improve the quality of the local analyses, the WFO in Miami has worked on incorporating additional local data networks into the analysis via the Local Data Acquisition and Distribution (LDAD) system, which is a component of AWIPS. This effort has led to a substantial increase in the amount of surface data going into the analyses. Figure 3 illustrates the increase in data availability to the forecasters and to the LAPS analyses.

An example of the qualitative impact on the surface analyses from these non-standard surface reporting sites is shown on Fig. 4. The addition of the non-standard inland stations, including those around Lake Okeechobee, enhances the LAPS analyses of both inland and coastal gradients as well as the effect of the lake on the surface fields. The availability of these additional data and their ingest into the analyses increases the ability of a forecaster to monitor changing surface conditions that could lead to critical short term forecast updates and warnings.

Quantitatively, the inclusion of the non-standard data sources (or mesonets) results in a substantial improvement of the analysis versus the background field, in this case, the 1 hour RUC40 forecast. Table 1 shows the average root mean square (RMS) errors for four basic surface fields calculated for the background and analysis fields separately throughout the study period using first the analyses that used only standard (metars, CMANS, and buoys) data networks, and then the analyses that used standard plus non-standard (mesonets) data networks across the LAPS domain. With respect to the standard RUC40 background field, the LAPS analyses had 20% to 30% smaller errors in the RMS for the temperature and mean sea level pressure (MSLP) fields when using standard data sets only, and up to 60% smaller errors when incorporating the mesonets into the LAPS analyses. For the dew point and wind speed fields, the improvements went from 4% to 11% and from 6% to 20%, respectively.

b. *Workstation Eta*

The Workstation Eta is a version of the National Centers for Environmental Prediction (NCEP) Eta model (Black 1994; Chen et al. 1997; Janjic 1994, 1996; Rogers et al. 1995; Zhao et al. 1997). It is a complete, full-physics system nearly identical to the operational Eta model. It is supported by the NWS Science and Operations Officer (SOO) Science Training and Resource Center (STRC) (Available online at http://strc.comet.ucar.edu/), which is part of COMET administrated by the University Corporation for Atmospheric Research (UCAR). The workstation Eta has one-way nesting capability, support for NCEP reanalysis grids, and support for NCEP Eta 12km output files for boundary and initial conditions. The workstation Eta does not, however, include support for LAPS ingest into the initialization cycle as delivered. That capability was added as part of this study.

c. *WSR-88D rainfall data*

The model skill was measured by quantifying its ability to forecast precipitation. The WSR-88D three-hourly rainfall totals from AWIPS were assumed to be ground truth for calculating performance metrics. These totals were archived throughout the study period. These data files were used to perform the model evaluation described in the following section.

3. Methodology

a. *WsEta configurations*

The WsEta model was run in four different configurations. The first one is referred to as the NWS WsEta (run locally at WFO Miami), which is configured similarly to the NCEP operational Eta, but ran at a higher resolution (10km versus 12km at NCEP). This run was initialized from the operational Eta 12. The second and third runs are referred to as the UM Eta9 (9 km) and UM Eta3 (3 km) runs. These are the outer and inner domains of a nested grid configuration, respectively. These nested domains were run at the University of Miami in partnership with the Miami WFO. The UM runs were different in configuration than the NWS runs. Specifications for each of these three runs are given in Table 2. The NWS WsEta is chosen to be the control run since it is similar to the NCEP operational Eta run.

Table 2 indicates that the operational Eta 12 was used for boundary and initial conditions of the NWS WsEta and UM Eta9 runs, whereas UM Eta9 was used for boundary and initial conditions of the UM Eta3 runs. LAPS analyses were used for initial conditions of the UM Eta3 runs only. In reality, four different model configurations were investigated: NWS WsEta; UM Eta9; UM Eta3 initialized with UM Eta9; and UM Eta3 initialized with LAPS. NCEP's Real Time Global Sea Surface Temperature (RTG_SST) (Thiebaux et al. 2001) analyses were used at the surface boundary.

Figure 5 shows the domain of the NWS WsEta and UM Eta9 (Outer) runs as well as the UM Eta3 (Inner)

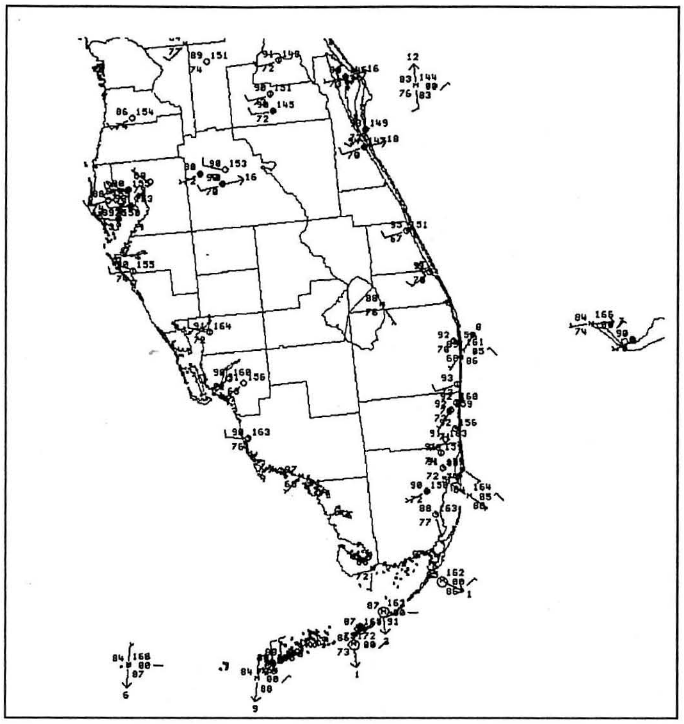

Fig. 3a. Typical surface data availability across WFO Miami LAPS domain from standard data networks (METAR, Buoys, CMAN, Ships).

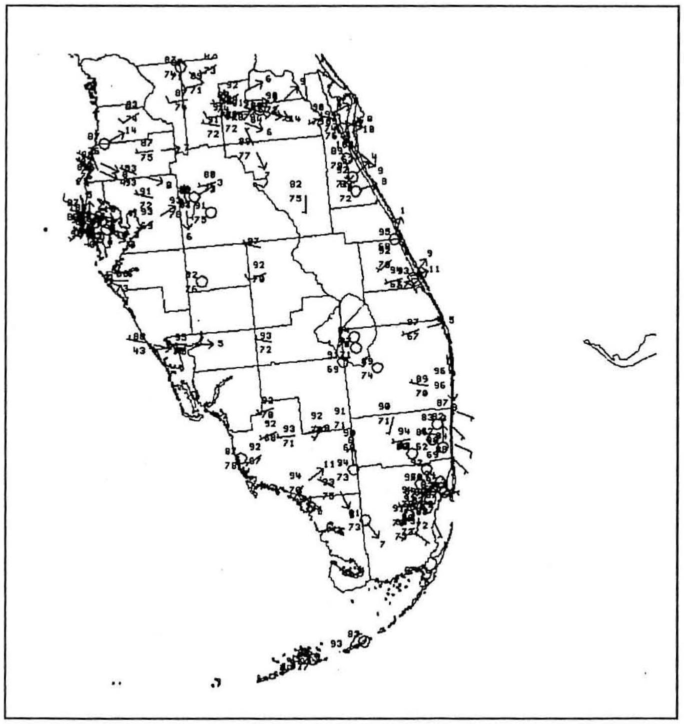

Fig. 3b. Typical plot of surface non-standard (mesonets) data networks ingested into AWIPS and the LAPS analyses at WFO Miami.

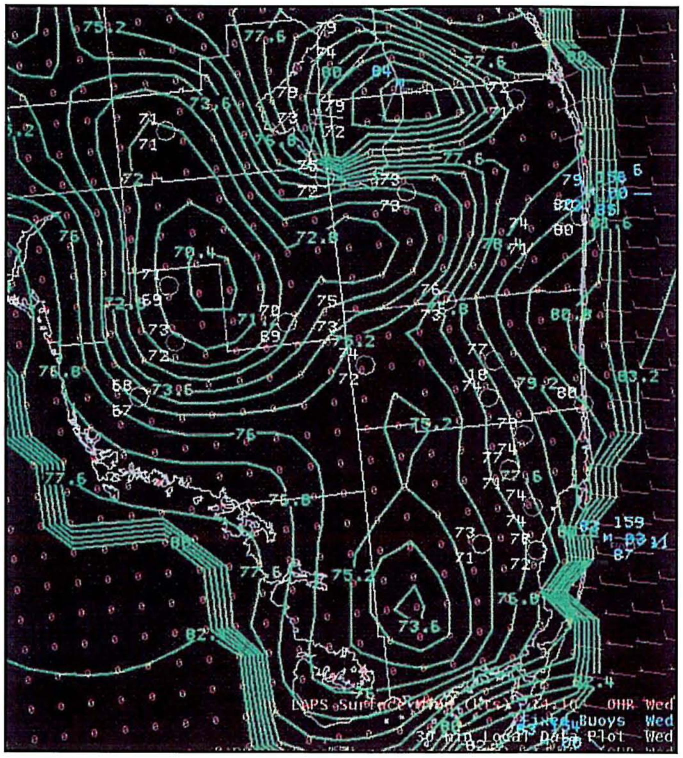

Fig. 4. LAPS surface temperature analysis for 1100 UTC 14 July 2004. Sites annotated in white depict locations of the non-standard surface observations that are ingested into the analysis.

runs. The inner domain, UM Eta3, follows WFO Miami mainland county warning area while the outer domain falls within the LAPS analysis and is nearly identical to the NWS WsEta domain. Due to bandwidth limitations, the Eta 12 output is made available by NCEP in tile files covering different sectors across the country. Figure 6 shows the Eta 12 tile files regions used as boundary and/or initial conditions as described in Table 2. These tile files were chosen to cover the domain of the experiment. During our experiment, the predominant upstream wind flow was from the east as illustrated in Fig. 7 by the NCAR/NCEP 1000 mb wind field reanalysis for the time period of the experiment.

b. Model evaluation

The model evaluation is based on analyses of grid point calculations of threat scores (TS), mean algebraic error (BIAS), and probability of detection (POD) for different precipitation thresholds. Summertime rain in South Florida is convective and cellular in nature. That means locally heavy rain is likely with any cell that develops depending on its movement. To ascertain the model ability to handle that better, the 0.25, 0.50, and 1.00 inches precipitation thresholds were used in this study instead of lower thresholds. However, we do not intend to suggest these thresholds to be the standard in assessing model skill.

Given an Area Forecast (Af) of precipitation, an Area Observed (Ao) of precipitation, and the area over which both of these intersect, referred to as Area Correct (Ac), the threat score, TS, is defined as:

$$TS = \left(\frac{Ac}{Af + Ao - Ac} \right) \qquad (1)$$

The smaller the threat scores the less skill in the forecast. If the area forecast and area observed are identical, then Ac = Af = Ao, and the threat score is 1. If the forecast and observed areas are the same size and half overlap, then Af = Ao = 1, whereas Ac = 0.5 and TS = 1/3.

The bias score is simply the average of the difference between model forecasts and observed values over all grid points. In mathematical form, the bias score for N number of grid points is:

$$BIAS = \frac{1}{N}\sum_{i=1}^{N}(M_i - R_i) \qquad (2)$$

where M_i and R_i are the model forecasts and observed precipitation at each grid point, respectively.

The probability of detection (POD) is defined as:

$$POD = \left(\frac{Ac}{Ao} \right) \qquad (3)$$

where Ac is the number of observed rainy grids that were forecast and Ao is the total number of observed rainy grids. Ideally, one would like a high POD. A POD of 1.0 would mean that every grid point that received rain was accurately forecasted. The primary difference between POD and TS is that POD does not penalize for over-forecasted precipitation.

These quantities (TS, BIAS, and POD) were calculated for each of the four model configurations shown in Table 2 during the study period. These statistics were calculated for both the 0600 UTC and the 1800 UTC runs separately, and averaged over the study time. The grid used for analysis of these values was the UM Eta9 grid. The scores were

Table 2. Model information and associated configurations. CP refers to convective parameterization with BMJ being Betts-Miller-Janjic parameterization (Betts and Miller, 1986; Janjic, 1994), and KF being Kain-Fritsch (Kain and Fritsch, 1993). BC and IC refer to the boundary and initial conditions used, respectively. Eta 12 refers to NCEP's operational Eta 12 km tile files used for either BC or IC. LAPS was used to initialize the UM Eta3 runs only.

Model Name (Res)	Cycle	Length	Mode	CP	BC	IC
NWS WsEta 10 km	06Z, 18Z	18 Hrs hourly output	Hydro-static	BMJ	Eta 12	ETA 12
UM Eta9 9 km	06Z, 18Z	18 Hrs hourly output	Non-Hydro-static	KF	Eta 12	Eta 12
UM Eta3 3 km	06Z, 18Z	18 Hrs hourly output	Non-Hydro-static	None	UM Eta 9	UM Eta9/ LAPS

calculated from 135 model runs. For each model cycle, the statistics were stratified into two periods. In the 0600 UTC cycle, the periods are the 1200 UTC to 1800 UTC (6-12 hour forecasts) and the 1800 UTC to 0000 UTC (12-18 hour forecasts) time frames. In the 1800 UTC cycle, the periods are the 0000 UTC to 0600 UTC and the 0600 UTC to 1200 UTC time frames (6-12 and 12-18 hour forecasts, respectively). The first 6 hours of the forecasts were left out of the analysis because it was observed that all four model configurations had problems initiating and/or spinning up convection within this time frame, even when precipitation was already occurring (Shaw et al. 2001).

4. Results

Figure 8 shows the results for the TS and POD scores for all three precipitation thresholds for the 4 August – 11 October 2003 experimental period. For clarification purposes, 06Z-06-12 Hrs in the figure follows the convention CY-H1-H2 Hrs, which means forecast hours H1 to H2 from model cycle CY. Therefore, 06Z-06-12 Hrs means the 1200 UTC to 1800 UTC forecast period from the 0600 UTC model run. Overall, these figures illustrate that as the precipitation threshold increases, the accuracy of the NWS Eta decreases considerably. This degradation in performance appears to be associated with the Betts Miller Janic (BMJ) convective parameterization scheme, which creates large areas of light to moderate rainfall that do not resemble the convective cellular characteristics of summertime Florida rainfall. However, forecasting moderate amounts of precipitation over large areas ensures that rarely will a rainy gridbox not be forecast, and why, for the lowest precipitation threshold (0.25), the NWS Eta exhibited the best scores overall (ALL in the figure is for all time periods combined), and particularly during the early morning and late night hours (06Z-06-12 Hrs and 18Z-12-18 Hrs). At the larger thresholds, the UM Eta9 and UM Eta3 runs had better scores.

During the sea breeze driven part of the diurnal convective cycle, from 1800 UTC (2 p.m. EDT) to 0600 UTC (2 a.m. EDT), the UM Eta9 and UM Eta3 runs showed considerable forecast improvements over the NWS Eta. This is reflected in both the threat and POD scores of the 06Z-12-18 Hrs period for all precipitation thresholds. The 18Z-06-12 Hrs period also shows improvement over NWS Eta in both TS and POD scores for the higher precipitation thresholds, but only in the POD scores for the 0.25 threshold. These results are consistent with the fact that most summertime Florida precipitation is convective in nature and driven by mesoscale processes. Therefore, non-hydrostatic processes (missing from the NWS WsETA but present in the UM configurations) cannot be ignored.

Figure 8 also suggests that using LAPS as configured at WFO Miami to initialize UM Eta3 apparently does not have a significant impact on the UM Eta3 precipitation forecast accuracy. The percentage improvement of runs initialized from LAPS over runs not initialized from LAPS (NoLAPS) runs is shown in Fig. 9. Overall, the use of LAPS slightly decreases the model accuracy for all runs, with the exception of the 0600 UTC based runs, and then only at the 1.0 in precipitation threshold.

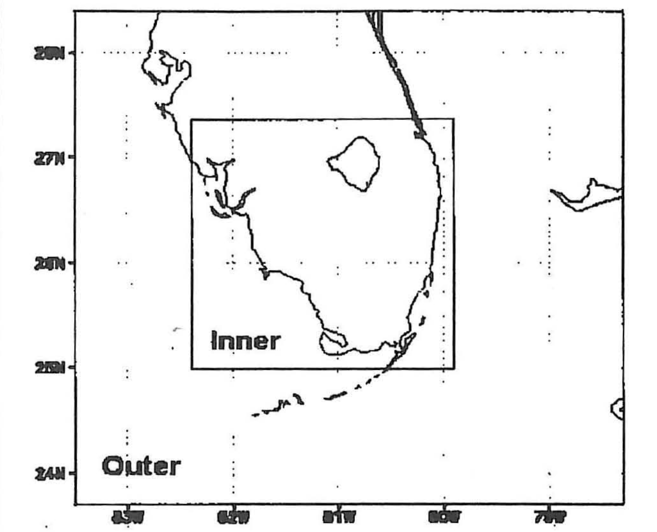

Fig. 5: Model domains for NWS WsEta (Outer), UM Eta9 (Outer), and UM Eta3 (Inner).

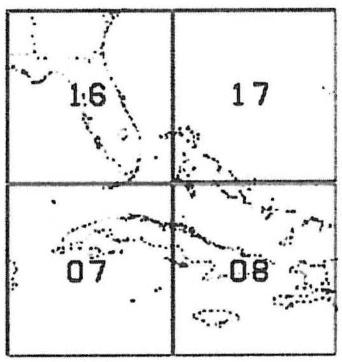

Fig. 6. Eta 12 tile files used as boundary and/or initial conditions as illustrated in Table 2.

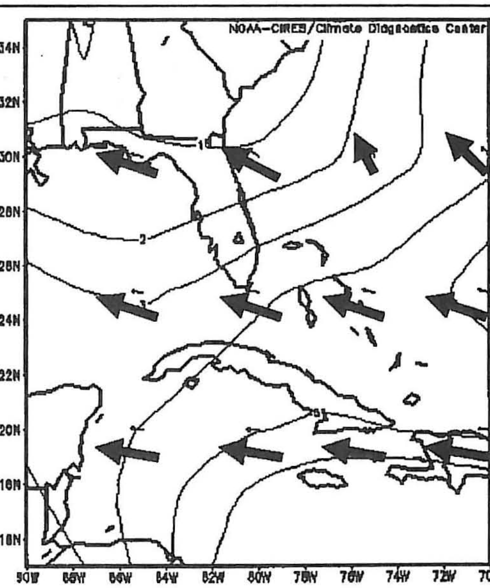

Fig. 7. Average 1000mb wind direction and speed for August and September 2003 from the NCAR/NCEP reanalysis field. Wind speeds in knots.

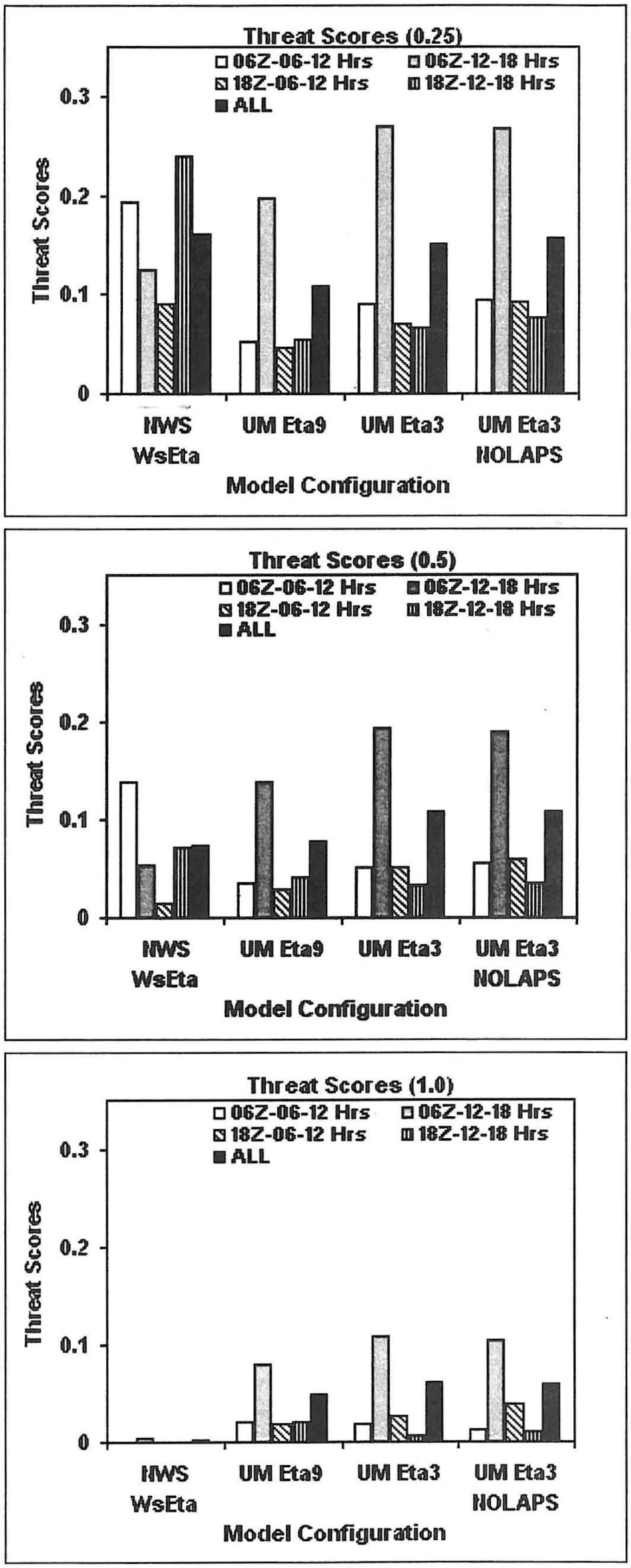

Fig. 8a. Threat scores (TS) for all four model configurations for 0.25 in (top), 0.5 in (middle), and 1.0 in (bottom) precipitation thresholds. **CYZ-H1-H2 Hrs** means for forecast hours H1 to H2 from cycle CY. ALL means all time periods combined.

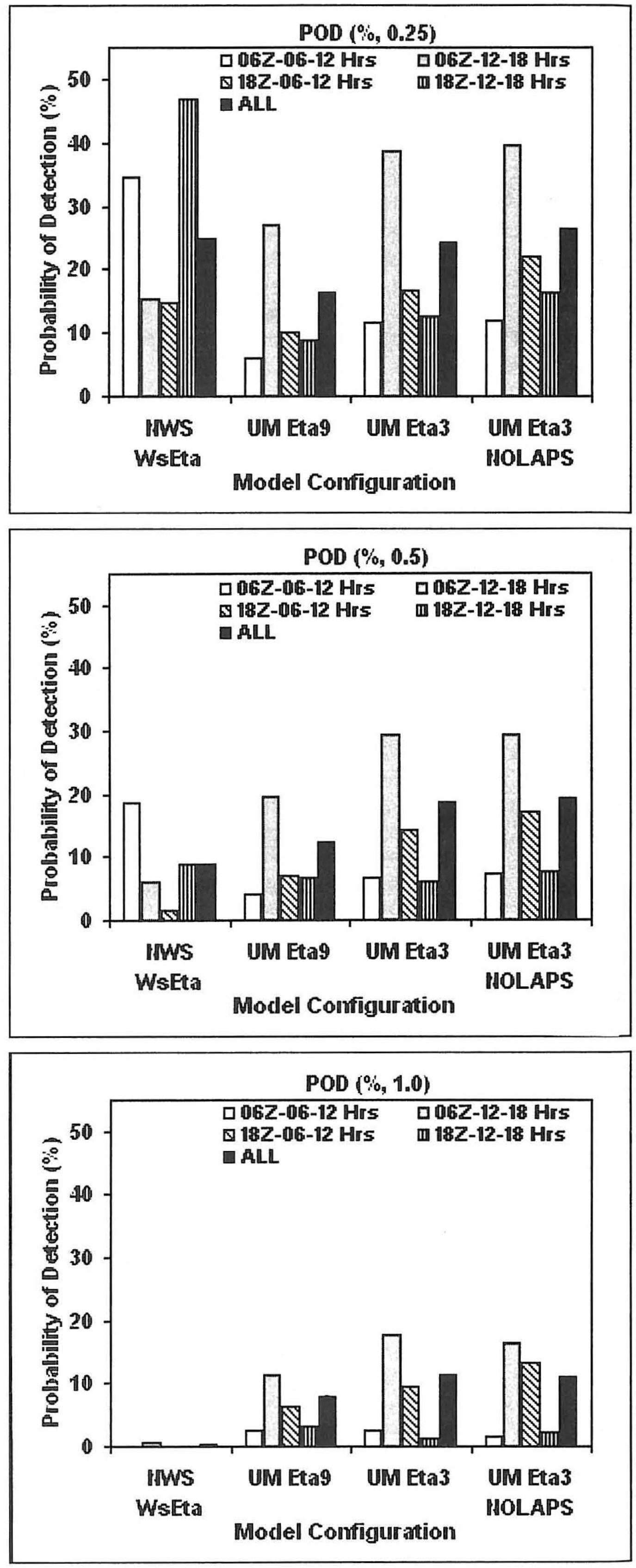

Fig. 8b. As in 8a but for probability of detection (POD).

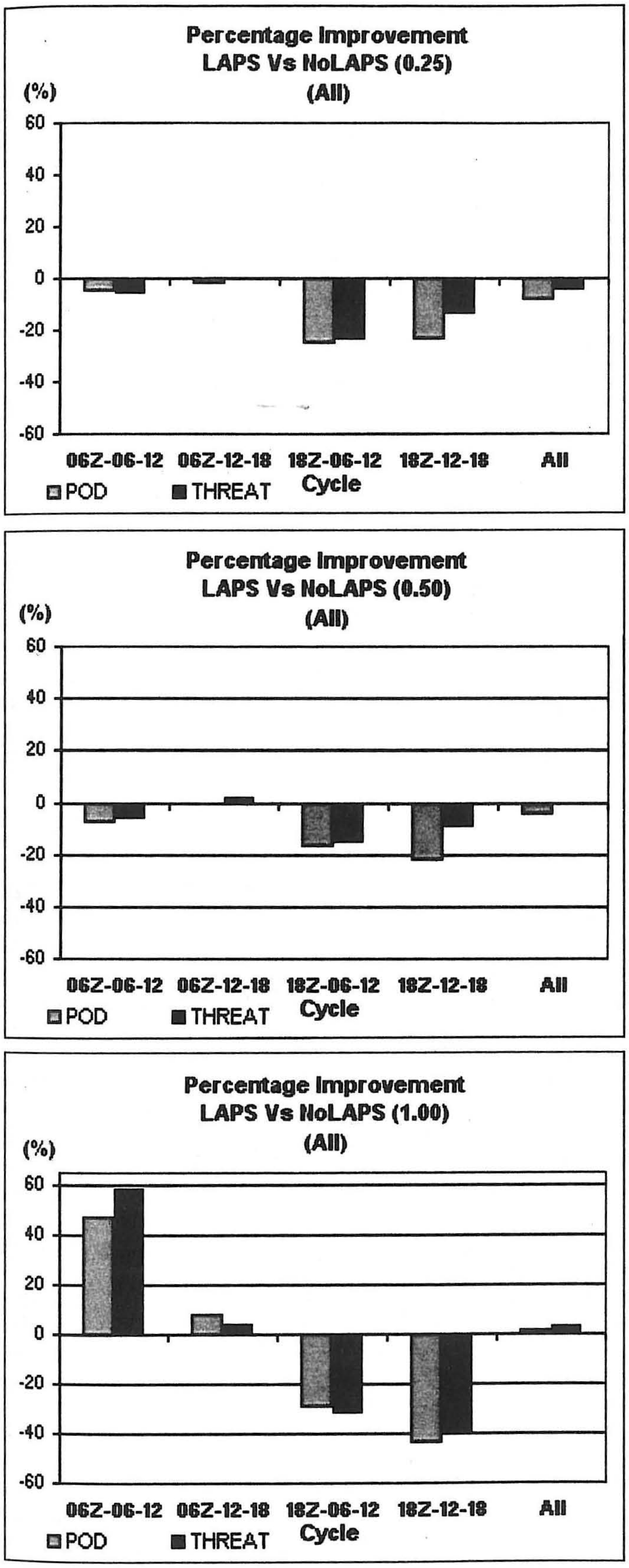

Fig. 9. Percentage POD and TS improvement of LAPS over NoLAPS UM Eta3 runs for 0.25 in (top), 0.5 in (middle), and 1.0 in (bottom) precipitation thresholds. **CYZ-H1-H2** means for forecast hours H1 to H2 from cycle CY. **All** in title means all wind regimes. **All** in time axis means all periods.

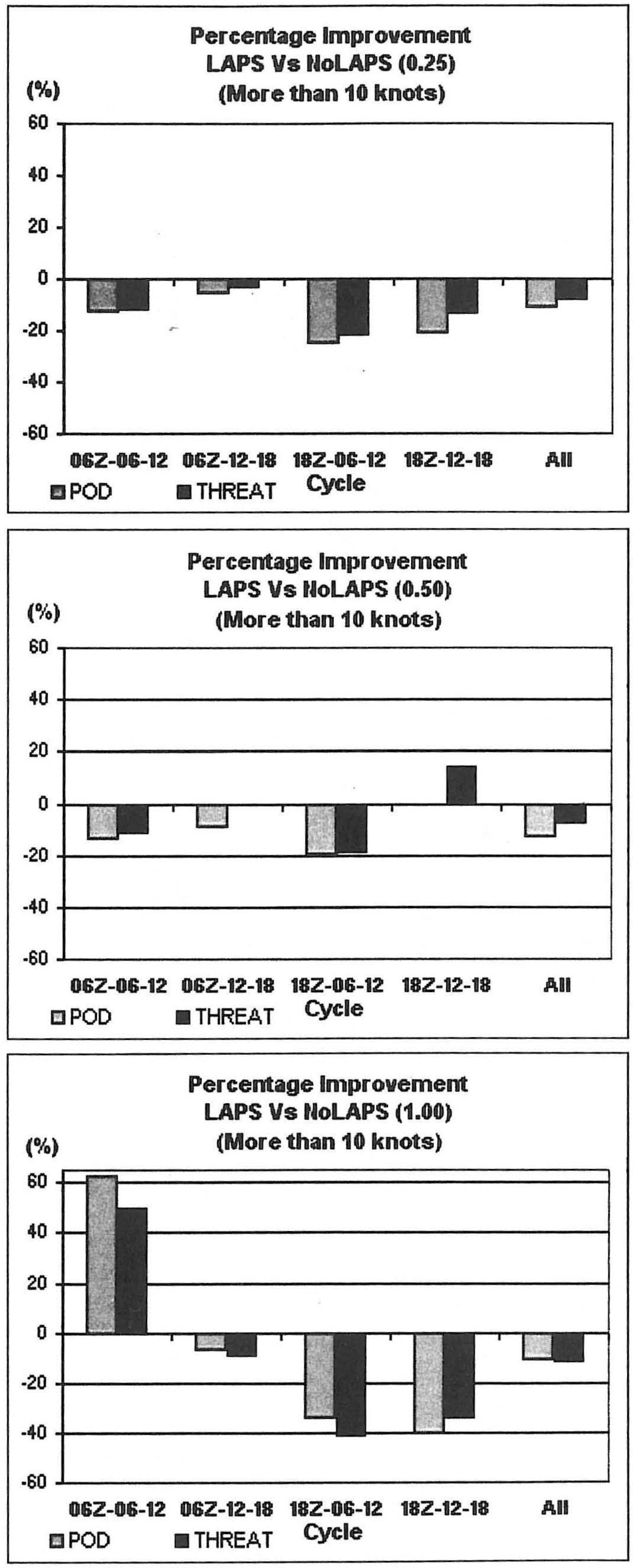

Fig. 10a. POD and TS improvement of LAPS over NoLAPS UM Eta3 runs when the domain average 925 mb and 10m wind speed was greater or equal to 10 knots for 0.25 in (top), 0.5 in (middle), and 1.0 in (bottom) precipitation thresholds. CYZ-H1-H2 means for forecast hours H1 to H2, cycle CY. **All** is for all time periods combined.

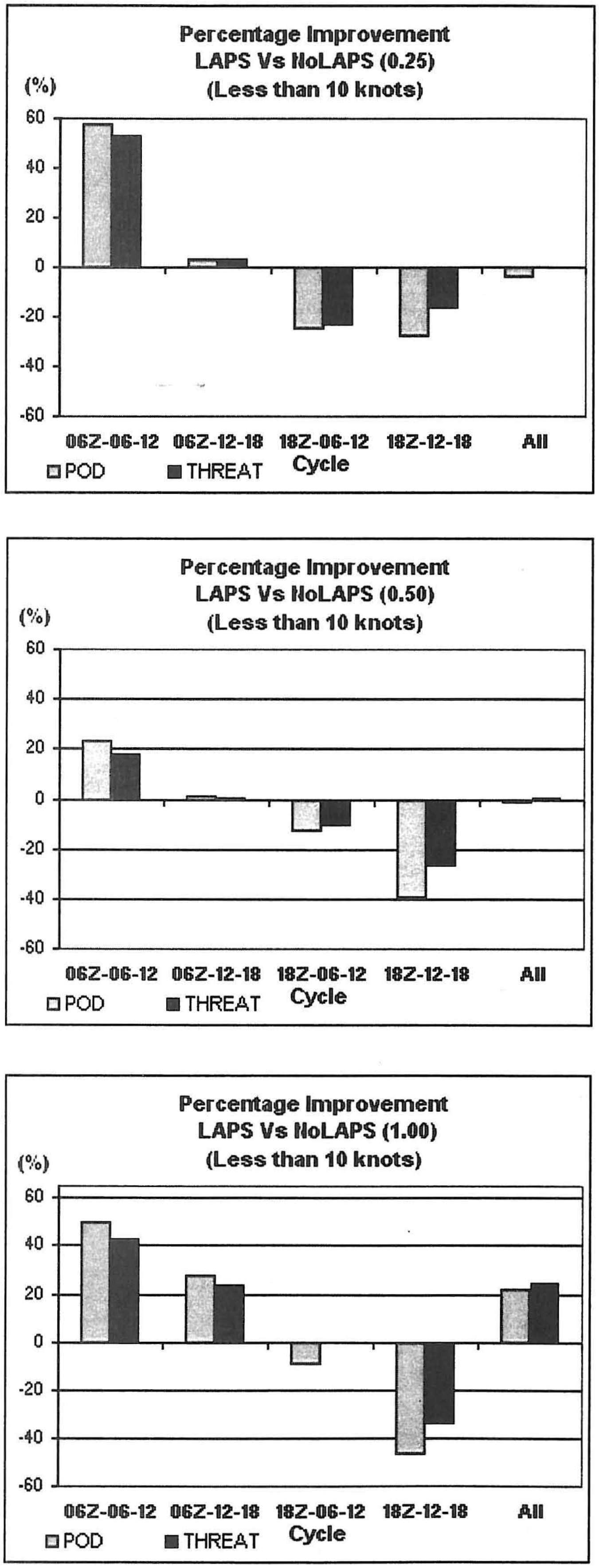

Fig. 10b. As in 10a but for wind speed less than 10 knots.

An analysis similar to that shown in Fig. 9 was performed, but cases were separated into "light wind" regimes and "non-light wind" regimes (Fig. 10). Light wind regimes were defined as having the mean value of 925 mb and 10 meter wind speeds averaged over the entire UM Eta3 domain, less than 10 knots. Non-light wind regimes had mean domain wide 925 mb and 10 meter winds of greater than or equal to 10 knots. In total, of the 135 model runs included throughout the experiment, 70 were classified as light wind regimes and 65 as non-light wind regimes. The purpose of this exercise was to separate, as much as possible, the sea breeze days from the days where synoptic features such as tropical waves or fronts might have influenced the flow across the domain. For the non-light wind regimes cases, runs initialized using LAPS as configured at WFO Miami had a negative impact on the UM Eta3 ability to forecast precipitation across the board, with the exception of the 06Z-06-12 Hrs period for the highest precipitation threshold (1.0 inch). However, for the light wind regime cases, LAPS shows a positive impact for all precipitation thresholds for both the 06Z-06-12 Hrs and 06Z-12-18 Hrs periods. For the 1.0 in threshold, the overall impact across all cycles and periods is positive in both scores. Notice also that the improvement is most substantial in the earlier hours of the integration (as much as 20% to 40% or higher), as expected because the boundary conditions dominate more in the latter hours of the integration (Schultz and Albers 2000).

An interesting result is that while UM Eta3 was the most skillful model for the afternoon and evening portion of the convective cycle, initializing UM Eta3 from the LAPS analysis did not have a positive impact for the 18Z-06-12 Hrs cycle as it did for the 06Z-06-12 Hrs runs. As previously mentioned in Section 2a, the AWIPS version of LAPS does not use the balancing as well as diabatic cloud analysis packages. The authors speculate that around 1800 UTC, convection is in general initiating or already going across the domain, and that the lack of these tools inhibits LAPS ability to properly resolve cloud structures and other critical mass field dependant features. This in part may be responsible for degrading the LAPS initialized forecasts at 1800 UTC for the UM Eta3 where sea breeze driven convection is ongoing through the late evening hours.

An example of the UM Eta3 precipitation forecast accuracy during the convective portion of the diurnal cycle is shown in Fig. 11. The figure shows two examples of 6-hourly precipitation amounts for three of the four model configurations shown in Fig. 8 (NWS Eta, UM Eta9, and UM Eta3 without LAPS) compared to the radar observed accumulations for the 06Z-12-18 Hrs period. This figure qualitatively illustrates the improved precipitation forecasts of the UM Eta3 run. The UM Eta3 appears to better resolve details of the spatial distribution when compared to the radar observed convective rainfall.

The results obtained from the TS and POD score analyses, namely the superiority of the UM Eta3 runs, are also reflected with the BIAS scores. Figure 12 illustrates the BIAS scores calculated and averaged for the study period for all model configurations. Overall (All for

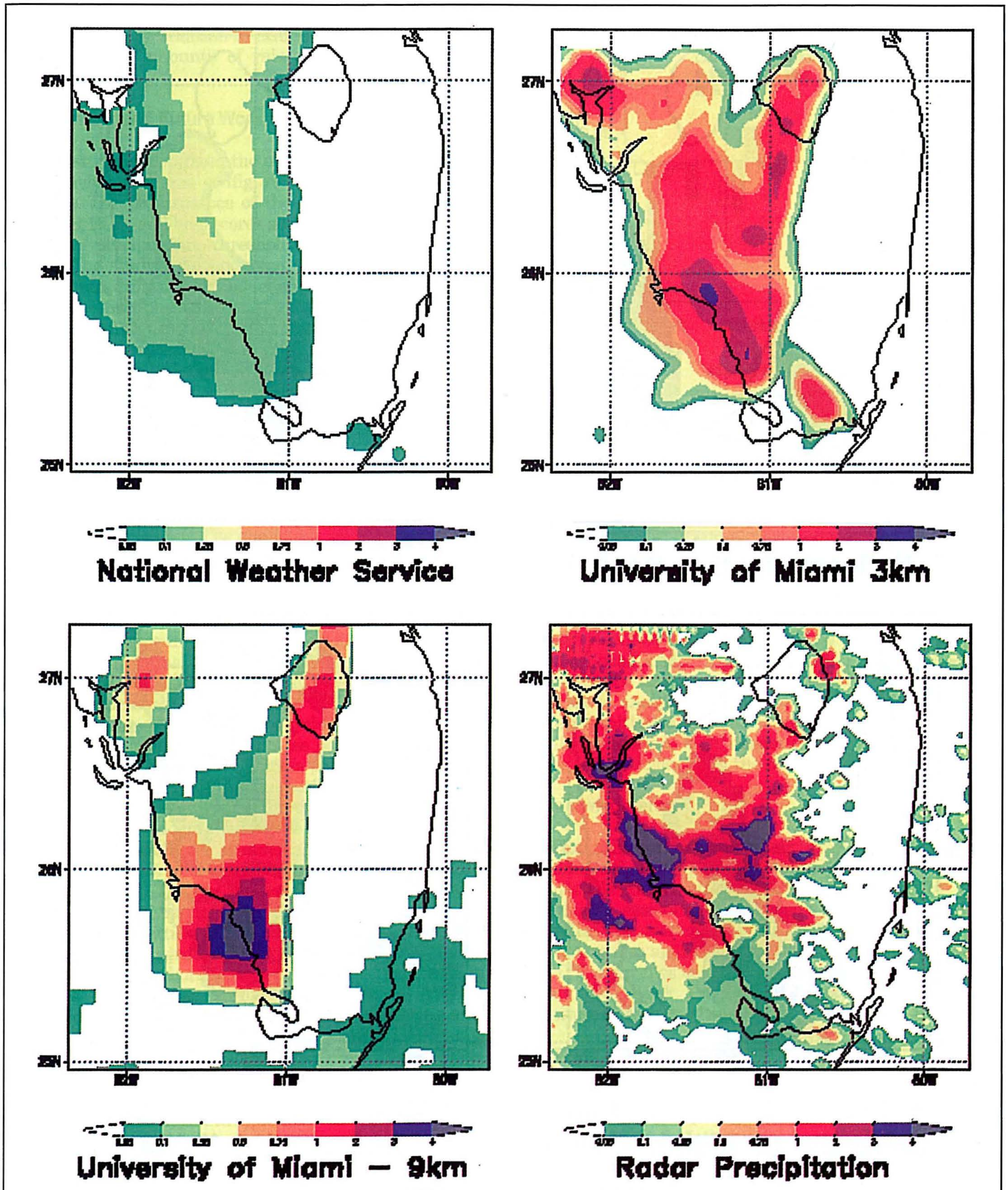

Fig. 11a. 18 UTC – 00 UTC precipitation forecasts from the 0600 UTC August 16, 2003 run from the NWS WsEta (top left), UM Eta9 (lower left), and UM Eta3 (top right). Lower right is the 6 hours radar observed accumulations. Threat Scores are 0.0 (NWS Eta), 0.25 (UM Eta9), and 0.37 (UM Eta3) for 0.5 inches precipitation thresholds.

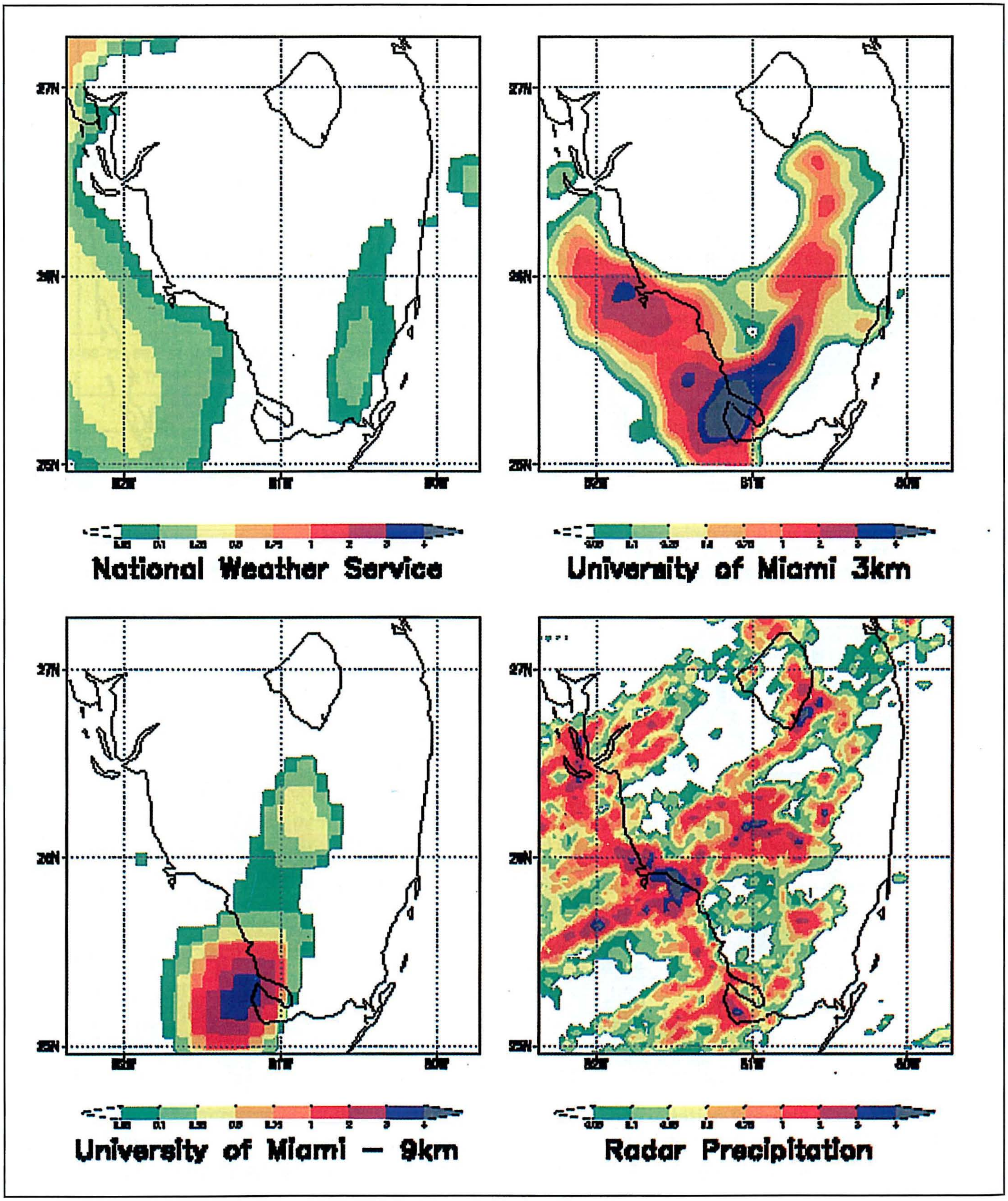

Fig. 11b. As 11a but for the 0600 UTC September 14, 2003 run. Threat Scores are 0.0 (NWS Eta), 0.11 (UM Eta9), and 0.29 (UM Eta3).

all periods combined), UM Eta9 and UM Eta3 show the smallest biases in addition to exhibiting higher skill forecasting higher amounts of rain as shown in Figs. 8 through 11.

5. Summary and Future Work

This study investigated the performance of the WsEta model using different configurations and initialization schemes. The performance of the model was measured using TS, POD, and bias scores across the model domains for three precipitation thresholds: 0.25, 0.50, and 1.0 inches. The study was conducted during the summer of 2003. Four different model configurations were compared. The first one was the NWS WsEta run at 10 km resolution, in hydrostatic mode, using the BMJ convective parameterization scheme and the Eta 12 tile files for boundary and initial conditions. The second configuration was the UM Eta9 run at 9 km resolution in non-hydrostatic mode, using the KF convective parameterization scheme, and the Eta 12 tile files for boundary and initial conditions also. The third configuration was the UM Eta3 run at 3 km resolution in non-hydrostatic mode using explicit grid scale precipitation, and UM Eta9 for boundary and initial conditions. The fourth configuration was the UM Eta3 configured as previously, but using the local mesonet enhanced LAPS analyses for initial conditions instead.

Results highlight that overall, the non-hydrostatic non-BMJ configurations show substantially higher skill in forecasting summertime precipitation amounts greater than or equal to 0.5 inches across South Florida, with the UM Eta 3 exhibiting the highest accuracy of all. This is particularly true with the afternoon and early evening portion of the convective cycle. Results also show that the impact of using LAPS, as configured at WFO Miami, to initialize the UM Eta3 is positive only in light wind regimes when land/sea breezes are the main forcing mechanisms at work driving the diurnal convection. In this case, observed improvements when using LAPS to initialize the model were as much as 20% to 40%. Most of this improvement was observed in the early morning runs (0600 UTC). Despite the fact that the UM Eta3 was the most skillful model with the afternoon and early evening hours portion of the convective cycle, the 1800 UTC runs were degraded when using LAPS to initialize the model. The authors believe one possible explanation for this is that the AWIPS LAPS, as of AWIPS Operational Build 3.0, did not utilize the balancing and diabatic cloud analysis packages. This hinders LAPS ability to properly resolve cloud structures and/or mass dependant fields. However, proving this hypothesis is beyond the scope of this one year project.

The results in this study illustrate the importance of having high resolution guidance available locally to the forecast offices. The results also illustrate that to fully realize the benefits of this guidance, the proper tools need to be made available at the local level. Incomplete data sets or diagnostic tools such as the version of LAPS available to the offices as of the time this experiment was conducted (with limited features and input data) does not fulfill the promise of a complete and robust local analysis and prediction system available locally to the forecast offices.

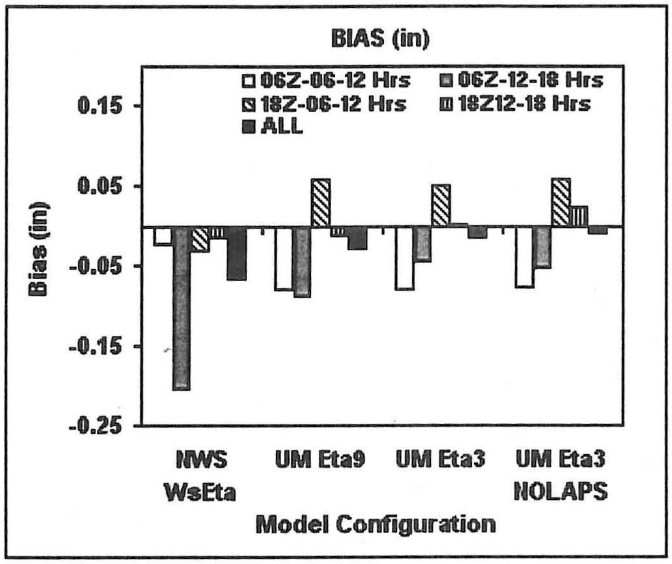

Fig. 12. BIAS scores for all model configurations and cycles. **CYZ-H1-H2** means for forecast hours H1 to H2 from cycle CY.

A follow-up project has recently been funded to extend the work in this paper to the Weather and Research Forecast (WRF) model. That work will consist of a similar experiment to the one presented in this paper, in that the locally run mesoscale model will be initialized using a locally produced, high resolution LAPS analysis. However, the LAPS analysis will be double the resolution with cloud analysis and diabatic initialization grids produced to initialize the WRF model. In addition, the use of locally generated, high resolution sea surface temperatures will be included in the new project.

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Authors

Brian Etherton was born in Tacoma, Washington on November 22, 1970. He earned a Bachelor of Science degree in Applied Mathematics from the Evergreen State College in 1992. He then moved to Sunnyvale, California, working for Lockheed-Martin Missiles and Space on the "NPOESS" satellite program (helping develop a ground-station prototype) while taking courses in meteorology at San Jose State University. He then attended Pennsylvania State University from 1996 to 2001, earning a Ph.D. in Meteorology in 2002. His dissertation focused on the use of ensembles in targeting and data assimilation. His Ph. D. advisor was Dr. Craig Bishop. Following graduate studies, he was a post-doc at the University of Miami involved in collaborative research with both the local National Weather Service office in Miami, as well as the Hurricane Research Division of NOAA's Atlantic Oceanographic and Meteorological Laboratory. In 2003, he began a position of assistant professor in the Geography and Earth Sciences program at the University of North Carolina at Charlotte where he helped establish the Bachelor of Science degree in Meteorology. He is also a member of the American Meteorological Society (AMS) and serves as President of the Charlotte local AMS Chapter. He lives in Charlotte, North Carolina with his wife Dana, who works in the mobile sources group of the air quality program in the Land Use & Environmental Services Agency for Mecklenburg County. His email address is: betherto@uncc.edu

Pablo Santos was born in Bayamón, Puerto Rico on September 18, 1969. He earned a Bachelor of Science degree in Physics from the University of Puerto Rico in 1992. He then attended Florida State University where he earned his Master of Science degree in Meteorology in the spring of 1995. In 1995 he started his career with the National Weather Service as a Meteorologist Intern in Jacksonville, Florida. Under the auspices of the National Weather Service University Assignment Program, Pablo attended Florida State University as a full-time meteorology graduate student during the academic year of 1997-98. During this time period he completed all courses and examinations required to become a doctoral candidate. He then returned to the NOAA/National Weather Service Weather Forecast Office in Jacksonville, Florida, where he worked as a general forecaster from August 1998 to June 2000 when he was promoted to Science and Operations Officer at the National Weather Service Weather Forecast Office in Miami, Florida. Upon returning to the National Weather Service in 1998 after his university assignment, Pablo continued to work on his doctoral dissertation. He defended it successfully in January 2003. Pablo has published three referred papers and several conference papers. He is also a member of the American Meteorological Society and the National Weather Association. He lives in South Florida with his wife Maria and two children, Pablo and Stephanie. His email address is: pablo.santos@noaa.gov

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