Data Assimilation and Model Evaluation for MM5 and COAMPS

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1. INTRODUCTION

During the summer time, thunderstorms along the central gulf coast are often widespread and occur frequently in the absence of synoptic-scale forcing. The sea breeze front is often a factor in the initiation of the storms. Some investigations on the influence of synoptic-scale flow on sea breeze are conducted based on either observation (Medlin and Croft 1998; Chiba et al. 1999) or numerical simulation (Arritt 1993). The numerical weather forecast, however, is strongly dependent on the accuracy of initial conditions. Data assimilation has been proved to be a major advance in NWP during past decades.

The work described here in is an attempt to explore the impacts of the data assimilation from non-conventional observations in mesoscale models, such as MM5 and COAMPS, based on a convective initiation database (sea breeze cases) at the central Gulf Coasts for the summer of 1996. Also, the comparison between these two models and observations are discussed.

2. NUMERICAL MODEL

The simulations from two meso-scale models, COAMPS (Hodur 1997) and MM5 (Grell et al. 1995), were analyzed. These models were run for the same triply-nested domains centered at the Mobile Bay, Alabama. with 49X49 grid points (27 km grid spacing), 43X43 grid points (9km spacing), and 43X43 grid points (3km spacing) for coarse, medium and fine meshes respectively (Fig. 1).

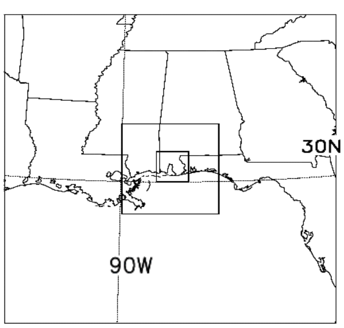

Figure 1. COAMPS/MM5 triple-mesh domain

2.1 COAMPS

The first numerical modeling system used is the Navy's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). This system consists of a data quality control system, a multivariate optimum interpolation (MVOI) analysis (Baker 1992), a fully-compressible, nonhydrostatic atmospheric model and an incompressible, hydrostatic ocean model cast in terrain following sigma-z coordinates. The model features explicit moist physics, and parameterizations for long-wave and shortwave radiation. The data assimilation scheme of incremental update is utilized.

2.2 MM5

The second numerical model is MM5 (version 3.4). Many researchers have successfully modeled atmospheric phenomena at high horizontal and vertical resolutions using MM5. In this study, the Kain-Fritsch convective parameterization is used at outer domain, while an explicit moisture scheme that includes prognostic equations for cloud water, ice, rainwater, and snow is employed on two finer domains. Radiation processes are handled using a cloud-radiation scheme where diurnally varying shortwave and longwave radiative flux interact with explicit cloud and clear air. The surface fluxes are used in the ground energy budget calculation. The planetary boundary layer (PBL) is modeled using the high-resolution Blackadar scheme coupled with a five-layer soil model. The analysis nudge technique has been used to assimilate the observations.

3. DATA SELECTION

One day, 5 June 1996, was selected based on the study of Medlin and Croft (1998). On that day, high pressure dominated the Gulf Mexico and coastal states. No detectable mesoscale boundaries and/or deep convective activity were present at 1200UTC so that the mechanics of local thunderstorm initiation could be studied as a function of sea breeze and boundary layer dynamics. A weak zonal flow and/or weak subsidence was prevalent over central gulf coast states with very light winds.

COAMPS simulation was initialized using 0000UTC Navy's global model (NOGAPS) with "cold start" mode for control experiment and with incremental update scheme for assimilation technique blending with radiosonde and surface observations.

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Lateral boundary conditions are given by NOGAPS analysis fields every 6 hours. The 30 vertical sigma levels were set at 10, 30, 55, 90, 140, 215, 330, 500, 750, 1100, 1600, 2300, 3100, 3900, 4800, 5800, 6800, 7800, 8675, 9425, 10175, 10925, 11675, 12425, 13300, 14300, 16050, 19400, 24400 and 31050m. Climate data of roughness, ground wetness, 500m resolution land sea temperature and 1km landuse data were used in simulations. The terrain data is 20km global database. On the other hand, MM5 was used to perform 24 hour simulation starting at 0000UTC in this case. The initial data were created by using NCEP gridded analyses (archived at NCAR) with rawinsonde and surface observations. The 23 vertical sigma levels were used. 2min (3.75km) terrain data and 10min (18.5km) landuse data were read for objective analysis. Since 0000UTC corresponds to 1800LST, the model runs the first 12 hours at nighttime, which allows enough spin-up time for the model. Thus, the analyses will primarily focus on the products from the 18hr forecast (1200LST) to 24hr forecast (1800LST).

4. RESULT

This case was characterized by calm, undisturbed conditions at night and in the morning. A front located in north part of Mississippi-Alabama states and a high system existed in north Gulf Mexico. A weak northeasterly flow prevailed in the morning until 1800UTC (12LST) (not shown). Three hours later, southerly wind dominated Mississippi-Alabama coastal areas. From radar images, convective system did not exist until 1835UTC in this area. The first echo appeared on east side of the Bay around 1935UTC. Convective cell developed and moved northwest ward till 2235UTC.

4.1 COAMPS and MM5 simulation with cold start

Of COAMPS simulation, northeast flow prevailed on surface in the early morning (not shown). At 1500UTC, almost calm wind controlled the land while 2m/s northeast wind dominated the Bay and sea surface, which agrees with the observation. Sea breeze established around noon. Fig.2 shows the surface wind from 1800UTC. It is evident that sea breeze developed at this time. There were two strong convergence caused by sea breeze. One located on the west side of the Bay and west coast. The other located east side and east coast. The Bay apparently was dominated by divergence. Sea breeze intensified with speed of 5-7m/s as well as it penetrated northward inland. Since then, sea breeze moved inland with intensity of wind increase.

The simulations of MM5 show that the northeast flows were prevalent on land whereas southeast wind dominated over ocean surface at 1200UTC (not shown). A convergence developed off shore. At 1500UTC, most parts of domain were southeast flow. A weak convergence zone located at east Bay. Three hours later, sea breeze developed well with the intensified south wind. Two noticeable convergences, located at northeast side of the Bay and Mississippi-Alabama boundaries, indicating convective activity enhanced.

The vertical velocity of COAMPS shows an inconsistent distribution with MM5. At 1500UTC (Fig.3), most parts of land were prevailed by down motion. Up motion located near southwest part of the Bay. Two vertical motion zones "symmetrically" located on the two sides of the Bay established at 1800UTC. It is noticed that strong downward motion was over the Bay surface. The two up motion zones intensified, enlarged and penetrated northward subsequently. MM5 provided more sporadic results for vertical velocity forecasts compared with COAMPS. The rising zone located offshore as no vertical motion appeared on land at 1500UTC (not shown). At 1800UTC, up motion developed on the land. The large and strong rising was on the eastern side and it was close to the Bay. This is because the sea breeze opposed base flow, which intensifies the development of sea breeze (Arritt, 1993), and synoptic flow retards inland penetration of sea breeze. As sea breeze front developed, positive vertical velocity became strong and move further inland.

COAMPS failed to simulate the precipitation of this convective system. From 1500UTC, there was no rainfall available from simulation, neither did cloud. The cloud mixing ratio at lower levels demonstrated the constant value of zero in whole domain. On the other hand, MM5 provided much big precipitation during the same period. Fig.4 shows the precipitation of MM5 simulation from 1500UTC to 1800UTC. There was a precipitation area located on the west of the Bay, which agrees with the observation. Strong rainfall occurred over the sea. Three hours later, the precipitation area still existed on the west of the Bay. The other two precipitation regions demonstrated unreasonable rainfall, nearly 40mm of maximum rainfall at the center during three hours.

Surface temperature and surface dew point temperature at Mobile, Alabama were selected from COAMPS and MM5 simulation (Fig.5a, and Fig.5b). The surface temperature and dew point at this point were calculated using five points average. The observations were obtained from surface weather map. COAMPS underestimated initial surface temperature and dew point. But temperature diurnal variation looks well. MM5 used accurate initial surface temperature in comparison. The magnitude of temperature diurnal variation, however, was quite small. Initially, the dew point difference between two models was nearly 2 degrees. But in the next day afternoon, air became very dry for COAMPS while quite wet for MM5. This is probably the reason why no precipitation from COAMPS but large amount of rainfall from MM5.

4.2 The simulations of COAMPS and MM5 with data assimilation utilization

The wind fields of COAMPS had the same evolution process as that without data assimilation (not shown). No apparent improvement was noticed. The precipitation, however, was observed from the result. Fig.6 denotes rainfall between 1200UTC and 1800UTC. The precipitation distribution was characterized with broad pattern. The rainfall was small compared with observation. Also precipitation area covered most north part of domain. After 1800UTC, no rainfall was available from simulation. The cloud presented after sea breeze establish. But it only exists from 2100UTC through 2400UTC.

There is a much improvement on wind fields of MM5 after using assimilation technique. At 1200UTC, weak north even calm wind presented over land. At 1500UTC(Fig.7a), sea breeze was developing but north wind still control the domain. A developed sea breeze showed up along coastal lines at 1800UTC(Fig.7b), and the south wind was prevalent instead of north wind. This agrees well with the observation. Data assimilation utilization suppresses the rainfall. Very small amount of precipitation were available after sea breeze establish. Most precipitation areas located over the ocean (Fig.8).

In order to intuitively display the process of sea breeze establishment, we will present the wind and temperature fields using CAVE5D visualization technique during the conference.

5. CONLUSION

Based on one case study, COAMPS and MM5 successfully simulated sea breeze initiation, development and penetration. COAMPS simulations revealed that sea breeze established at local noon. MM5 simulations, on the other hand, preceded the observational sea breeze establishment. COAMPS simulations were characterized by broad pattern while MM5 by sporadic feature. No precipitation and cloud were produced from COAMPS with cold start mode. Data assimilation improved the prediction of rainfall while no significant enhancement was observed for other parameters. MM5 overestimated precipitation and cloud without data assimilation. The rainfall was suppressed after using data assimilation. Further more, utilization of analyses nudge in MM5 provided more accurately temporal establishment of sea breeze.

6. ACKNOWLEDGMENT

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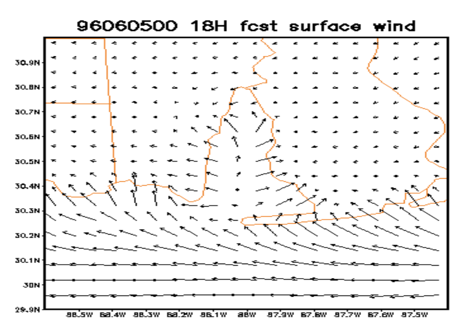


Figure 2. Surface wind of COAMPS simulation at 1800UTC on June 5,1996.

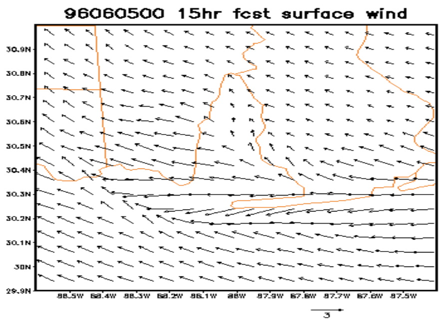


Figure 3. Surface wind of MM5 simulation at 1500UTC on June 5,1996.

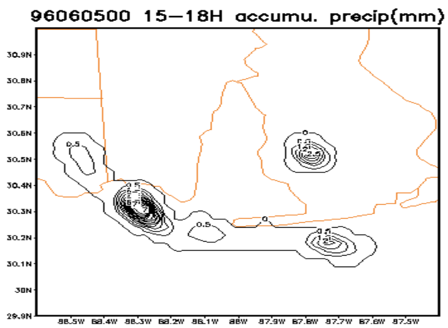


Figure 4. Precipitation (mm) of MM5 simulation during the period of 1500UTC through 1800UTC on June 5,1996.

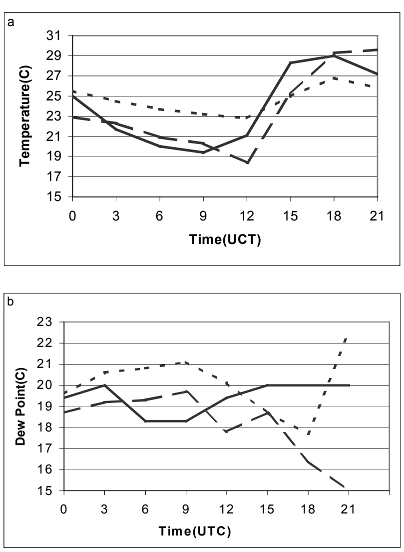


Figure 5. Surface temperature (a) and dew point temperature (b) from observations (solid lines), COAMPS (long-dashed lines) and MM5 (dotted lines)

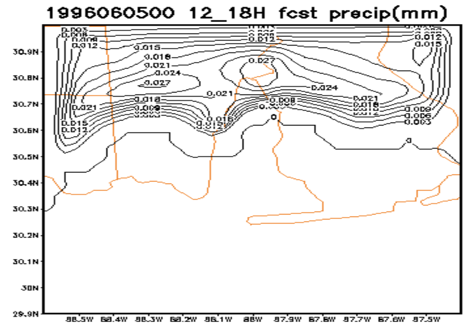
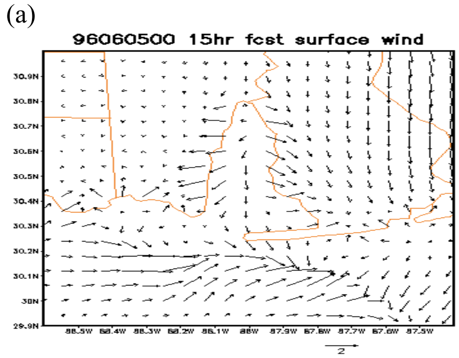


Figure 6. Precipitation (mm) of COAMPS simulation with data assimilation during the period of 1200UTC through 1800UTC on June 5,1996.

(a)



(b)

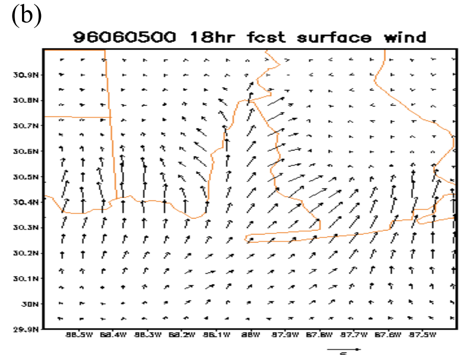


Figure 7. Surface wind of MM5 simulations with data assimilation at (a) 1500UTC and (b) 1800UTC on June 5,1996.

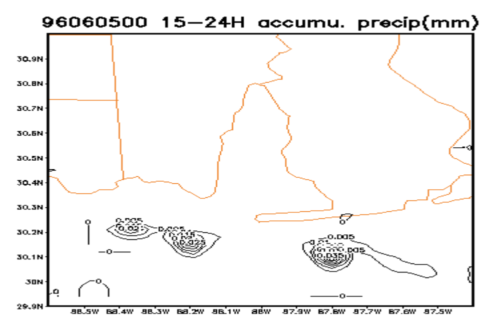


Figure 8. Precipitation of MM5 simulation with data assimilation during the period of 1500UTC through 2400UTC on June 5,1996.