4.8 EFFECT OF MESOSCALE PROCESSES ON BOUNDARY LAYER STRUCTURE AND PRECIPITATION PATTERNS: A DIAGNOSTIC EVALUATION AND VALIDATION OF MM5 WITH NC ECONET OBSERVATIONS

Aaron Sims, Dev dutta S. Niyogi, and Sethu Raman
North Carolina State University, Raleigh NC

INTRODUCTION: Mesoscale processes, dictated by surface characteristics, play a dominant role in the development of the planetary boundary layer (PBL) structure and the formation of convection. The effect of mesoscale processes on the boundary layer structure also has significant implications in the understanding of circulation patterns and regional scale predictability. Large geographical variability in North Carolina (NC) provides a wide variety of weather events and climatological regimes. There are many challenges for numerical modeling in NC due to the heterogeneity in topography, land use, and soil type, presence of the ocean and the Gulf Stream. These heterogeneous attributes feature an excellent location for simulations and validation of the MM5 numerical modeling system with observations of high spatial and temporal resolution.

EXPERIMENTAL: Two cases are simulates using MM5: a non-precipitation case and a convective case including precipitation with a 5-km domain centered over the Carolinas. Model integration is for 72 hours from 0000Z August 15, 2000 to 0000Z August 18, 2000. Simulated hourly surface and sub-surface values are evaluated against in-situ surface observations from the North Carolina Environmental and Climate Observing Network (NC ECO Net). These simulations consist of real case studies involving MM5 Version 3 with the MRF PBL scheme coupled to the Oregon State University (OSU) land surface model (LSM). The OSU LSM uses 1 km resolution land-use and soil data as input into MM5 for capturing the dynamics of land-surface forcing.

The acquisition and combination of different agro-meteorological data across NC provides high-resolution observations used for validation at multiple model grid points. For the case studies, these data incorporate hourly observation sites throughout North Carolina including 19 ASOS (Automated Surface Observing Sites / owned and operated by the NWS and FAA) sites and 15 ECONet (Environmental and Climate Observing Network: maintained by State Climate Office of North Carolina) sites. Multiple parameters compared and investigated using this network of observations include: ECONet: Air Temperature (2m), Relative Humidity (2m), Wind Speed (10m), Wind Direction (10m), Soil Temperature (10 cm), Soil Moisture (10cm), Hourly Precipitation rate; ASOS: Air Temperature (2m), Dewpoint (2m), Wind Speed (10m), Wind Direction (10m), Hourly Precipitation, Weather Conditions, and Cloud Layers.

Corresponding Author: Dr. Dev Niyogi, State Climate Office of North Carolina, North Carolina State University, Raleigh, NC 27695 – 7236. Tel: 919 513 2101; Fax: 919 515 1441;email:dev_niyogi@ncsu.edu.

A summary of the station locations is given in Fig1 and its GIS based coordinates are shown in Table 1. These simulated wind fields are used to investigate local land-sea interactions near the coast, effects of land surface processes in the piedmont, and pollution transport potential over complex terrain in the mountains of North Carolina. Precipitation patterns generated by the model are also compared with daily observations of precipitation amounts in conjunction with the hourly stations across the central portion of the 5 km domain, particularly North and South Carolina. Figure 2 shows a sample time series for the observed and the simulated 2 m temperatures. The model results indicate a consistent over prediction of the nighttime air temperatures that needs to be evaluated further.

Following a graphical comparison of 2D and 3D fields, quantitative and descriptive statistical methods are applied to provide relationships for errors and biases in the simulations. The analyses give additional insight into model performance. This is especially important when validating complex and comprehensive interactions and processes that occur in North Carolina. Statistical measures used include: absolute correlation, root mean square error (RMSE), bias, normalized mean square error (NMSE), weighted normalized mean square error of the normalized ratios (WNNR), normalized mean square error of the distribution of the normalized ratios (NNR), and the index of agreement. Figure 3 shows a GIS based plot of the index of agreement between the 72 h observed and the modeled air temperatures. Despite the relatively high resolution (5 km grid spacing), the model performance in the mountain region is quite poor.

CONCLUSIONS: Diurnal variation is handled well by the model indicating that the thermodynamic structure of the atmosphere is well simulated. Nocturnal boundary layer processes are poorly simulated, particularly in western NC, and heterogeneous surface features have significant effects on regional scale processes including boundary layer structure and precipitation patterns. Model performance degrades over regions with complex terrain signifying that more observations are needed to develop regionally consistent flow patterns. Precipitation patterns are simulated with a fair amount of accuracy when including the Kain-Fritsch cumulus parameterization scheme.

REFERENCES

Sims A., 2001, M.S. Thesis, Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, Raleigh, NC 27695.

Fig. 1. Hourly surface observation stations across North Carolina. Triangle markers indicate ASOS stations. Circle markers indicate AgNet stations. The square marker indicates the location of the SODAR station.

STN_ID	AGENCY	CITY	STATE	LATITUDE	LONGITUDE	I	J
AKH	EXP	Gastonia	NC	35.20	-81.16	58	70
AVL	NWS	Asheville	NC	35.43	-82.54	62	45
BUY	EXP	Burlington	NC	36.05	-79.47	78	99
CAS	SCO	Castle_Hayne	NC	34.32	-77.92	43	130
CLA	SCO	Clayton	NC	35.65	-78.50	71	117
CLI	SCO	Clinton	NC	35.02	-78.28	58	122
CLT	NWS	Charlotte	NC	35.21	-80.95	59	74
ECG	FAA	Elizabeth City	NC	36.26	-76.18	88	156
EQY	EXP	Monroe	NC	35.02	-80.62	55	80
EWN	FAA	New Bern	NC	35.07	-77.05	61	144
FAY	FAA	Fayetteville	NC	34.99	-78.88	56	111
FLE	SCO	Fletcher	NC	35.43	-82.57	62	45
GSO	NWS	Greensboro	NC	36.10	-79.94	79	91
HKY	FAA	Hickory	NC	35.74	-81.38	70	66
HSE	NWS	Hatteras	NC	35.23	-75.62	67	169
IGX	EXP	Chapel Hill	NC	35.93	-79.06	76	107
ILM	NWS	Wilmington	NC	34.27	-77.91	42	130
INT	FAA	Winston Salem	NC	36.13	-80.22	79	86
JAC	SCO	Jackson Spring	NC	35.22	-79.73	60	96
KIN	SCO	Kinston	NC	35.37	-77.55	66	134
LAU	SCO	Laurel Springs	NC	36.40	-81.30	84	67
LBT	EXP	Lumberton	NC	34.61	-79.06	48	109
LEW	SCO	Lewiston	NC	36.13	-77.17	84	139
MEB	EXP	Maxton	NC	34.79	-79.37	51	103
MRH	EXP	Beaufort	NC	34.73	-76.66	54	151
OXF	SCO	Oxford	NC	36.28	-78.62	85	114
RDU	NWS	Raleigh/Durham	NC	35.87	-78.79	75	111
REE	SCO	Reedy Creek	NC	35.81	-78.74	74	112
REI	SCO	Reidsville	NC	36.38	-79.70	85	95
ROC	SCO	Rocky Mount	NC	35.90	-77.72	78	130
RZZ	EXP	Roanoke Rapids	NC	36.44	-77.71	89	129
SAL	SCO	Salisbury	NC	35.70	-80.62	70	79
SOD	EPA	RTP	NC	35.89	-78.88	76	110
WAY	SCO	Waynesville	NC	35.65	-82.97	67	38
WHI	SCO	Whiteville	NC	34.40	-78.80	43	114
WIL	SCO	Williamston	NC	35.85	-77.03	78	142

Table 1. Hourly surface observation stations across North Carolina. Station ID, latitude, longitude and corresponding model grid points for the 5 km domain are listed

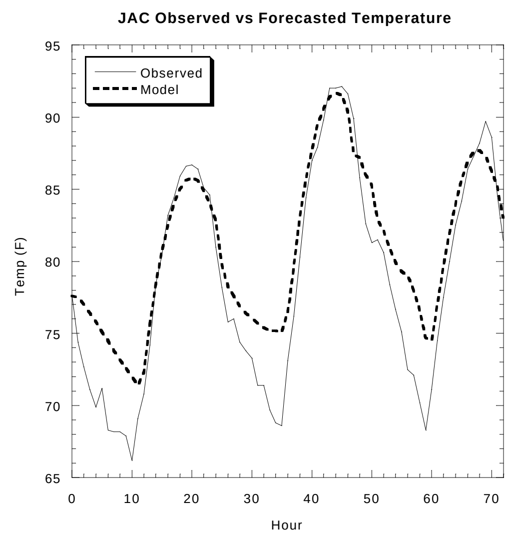

Fig. 2. Observed and modeled 2m temperature at Jackson Springs (JAC), NC. Forecast hours span 72 hours beginning at 0000Z (1900 LST) on August 15, 2000 and ending on August 18, 2000 at 0000Z (1900 LST). Modeled and observed temperatures are in phase and match well during the daytime. The model over predicts nighttime temperature

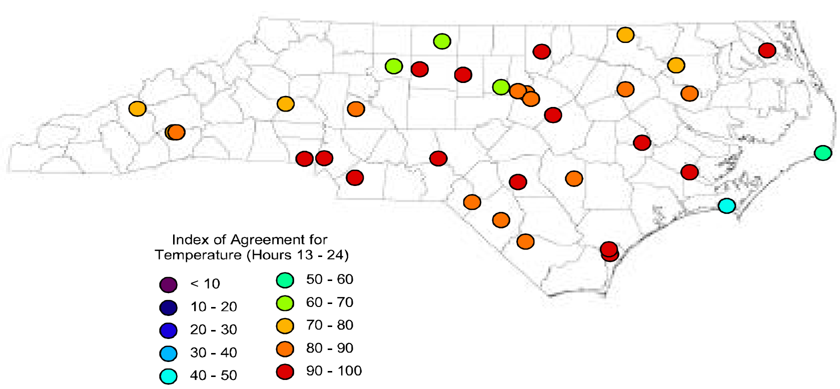

Fig. 3. Index of agreement for temperature between the model and observation stations at 2m-air temperature across North Carolina for the 72-hour period from 0000Z August 15, 2000 to 0000Z August 18, 2000