J3.5   THE EFFECT OF AVERAGING SURFACE ROUGHNESS VALUES ON COASTAL WINDS FOR DIFFERENT MESOSCALE MODEL RESOLUTIONS

Gueorgui V. Mostovoi, Pat J. Fitzpatrick[*], Yongzuo Li, Derrick Herndon, and Nam Tran
Engineering Research Center, Mississippi State University
Stennis Space Center, Mississippi

Elizabeth Valenti
WorldWinds, Inc.
Stennis Space Center, MS

1. INTRODUCTION

It is known that an increase in model resolution will generally produce superior forecasts. These improvements can partially be attributed to a reduction in phase speed and amplitude errors (Pielke 1984), better resolved cloud microphysics (Weisman et al. 1997; Gallus 1999), and improved wind forecasts in regions of topographical forcing, such as in downslope wind events or localized circulation patterns. In addition, more subtle improvements are achieved in regions of sharply contrasting surface characteristics, such as along the littoral coastal zone.

The purpose of this research is to examine the skill of surface fields produced by the Coupled Ocean Atmosphere Mesoscale Prediction System, or COAMPS (Hodur 1997), with a grid spacing of 9 and 27 km along the Louisiana and Mississippi coastal zone. Specifically, the domain chosen for the comparison covers the Gulf of Mexico littoral zone from Mobile Bay to the Atchafalaya Delta. Six-hour increments of the models are compared with observations from 22 surface stations. The results presented here are based on 12 simulations performed during 14-20 December 2001 initialized at 0000 or 1200 UTC, conducted out to 48 h. Initial and boundary conditions were provided by the Navy Operational Global Atmospheric Prediction System (NOGAPS) in "cold-start" mode. The 27-km runs used one domain which encompassed much of the southern U.S. and northern Gulf of Mexico, and the 9-km runs (covering the Louisiana, Mississippi, and Alabama Gulf Coast) were performed using two nests, with the 9-km runs imbedded in the same 27-km domain. Only a one-way nest interaction was used to simplify the analysis. The Land-Use mask for ground wetness, albedo, and surface roughness consists of 0.01 deg climatological data from the U.S. Geological Survey.

Frontal passage with vigorous shifting winds is common along the Gulf Coast in December. During this period of study, 4 cold fronts traversed the region. For this reason, and because wind forcing of ocean models in the littoral region is of primary interest to the Navy, this paper evaluates the higher resolution model wind field against the 27-km field along the Mississippi and Louisiana coast during this windy, transitional period.

2. OVERVIEW OF THE NORTHERN GULF OF MEXICO LITTORAL INITIATIVE (NGLI)

This study parallels the Northern Gulf of Mexico Littoral Initiative (NGLI), a multi-agency program established through a partnership between the Commander, Naval Meteorology and Oceanography Command and the Environmental Protection Agency's Gulf of Mexico Program Office. NGLI was established in 1999 to provide reliable, timely meteorological and oceanographic mesoscale models for the Mississippi Bight/Sound and adjoining bays through development and operation of a sustainable comprehensive nowcasting/forecasting system. This forecasting system includes operational 9-km meteorology forecasts using COAMPS, a high-resolution 3D ocean circulation model with sediment transport from the coastal estuary (ECOMSED) (Blumberg et al. 1987; 1999; 2001) with boundary conditions provided by the Princeton Dynalysis Ocean Model, or PDOM (Mellor 1998), and the Simulating WAves Nearshore, or SWAN (Booij et al. 1999; Ris et al. 1999), model.

These modeling systems will be evaluated using all regional in-situ meteorological, oceanographic, and river data. In addition, there have been seven cruises out into the Mississippi Sound and open Gulf to collect data, including core samples, ADCP measurements, CTD data, AC-9 data acquisition (all cruises), mooring work, and gravity surveys. Archived observations and model data will be distributed to a public access data server (the Master Environmental Library, or MEL, at http://mel.dmso.mil), and real-time observations and model forecasts will be displayed on the NGLI web site at: http://www.navo.navy.mil/NGLI . The interested reader is referred to these websites for more information about all facets of NGLI. The rest

───────────────
[*] *Corresponding author address*: Pat J. Fitzpatrick, Mississippi State Univ., ERC, Stennis Space Center, MS, 39529-6000; e-mail: fitz@erc.msstate.edu.

of this paper will focus on the case studies of COAMPS for the December 2000 period.

3. EVALUATION OF 9- and 27-km COAMPS' WIND FIELDS IN DECEMBER 2000 WIND FIELDS

A cursory examination of the December 10-meter model winds shows distinct differences between the 9- and 27-km COAMPS runs along the immediate coastlines. An example 12 h into the simulation for 19 December 2000 (initialized at 12Z) is shown for the 27-km run (Fig. 1) and for the 9-km run (Fig. 2). It is apparent that the 27-km run overpredicts the wind speeds along the coastal interface, particularly over the mouth of the Mississippi River, and in general does not capture the transition from land to ocean as well as the 9-km run.

To quantify these differences, wind speed observations from CMAN stations, moored buoys, and METAR stations are compared to the COAMPS fields. Where necessary, observations are adjusted to 10 m height, using a power-law profile (Arya 1988) with an exponent value equal to 0.2. Since standardized 1-min wind averages are desired, the moored buoys (which use 8-min averaging) are multiplied by an adjustment factor of 1.09 as suggested by Houston and Powell (1997). Using these observations, the 9-km COAMPS runs were validated against the 27-km runs by computing the bias (model minus observations) and skill score. The wind speed skill score (SS_{spd}) is computed by:

$$SS_{spd} = 1 - \frac{MAE_{9km}}{MAE_{27km}} \times 100\%$$

where MAE_{9km} is the wind speed mean absolute error of 9-km COAMPS, and MAE_{27km} is the mean absolute error of the "reference" 27-km COAMPS (Wilks 1995). A positive SS_{spd} shows the percentage improvement of the 9-km COAMPS versus the 27-km COAMPS. To develop a reasonable database in these calculations, and to simplify the analysis, 12-, 18-, 24-, 30-, 36-, 42-, and 48-h simulations are lumped together. An evaluation of the individual periods shows forecast degradation with time (as expected), but does not alter the results of this study.

Figure 3 shows the spatial distribution of wind speed bias for the 27- and 9-km COAMPS runs. While the 9-km exhibits a negative bias almost everywhere, the 27-km shows a distinct positive bias over southeast Louisiana and along coastal Mississippi, with a large overprediction of wind speed near the mouth of the Mississippi River delta.

In addition, at most locations a definite tendency for speed underprediction is observed for both models when wind speed exceeds 6 ms^{-1} (not shown). At the same time, both models demonstrate a persistent overestimation of wind speed for observed weak winds less than 2 ms^{-1} (now shown). Nearly all calm situations are not reproduced by either model well.

Using mean absolute error statistics, the skill of the 9-km wind speed simulations versus 27-km is shown in Fig. 4, which indicates a 40% improvement around the mouth of the Mississippi River. Lesser improvement (20-30%) is observed along the Mississippi Gulf Coast and southeast Louisiana marshes. Clearly, in these regions, a land-mask feature is not adequately resolved in the 27-km COAMPS. Interestingly enough, since the 9-km has an almost uniform negative bias, offshore forecasts southeast of Louisiana actually degrade a little compared to the 27-km COAMPS, since the latter's positive bias propagates itself into that region and partially offsets the bias. There is also skill degradation in the western domain due to these bias differences.

The domain-averaged skill of each simulation is shown in Fig. 5, indicating an improvement in 8 runs, degradation in 2 runs, and little skill score difference in 2 runs. The degraded skill scores are due to convectively-generated outflow boundaries. In COAMPS, for grid spacing less than 10 km, explicit treatment of cloud physics (Rutledge and Hobbs 1983) is employed; for coarser grid spacing, the Kain-Fritsch cumulus parameterization scheme (Kain and Fritsch 1990; Kain 1993) is used. This indicates that, in stochastic convective situations, high-resolution cloud-explicit models often generate non-representative wind fields, and presents new challenges for operational meteorologists interpreting the output, and for model developers hoping to improve mesoscale forecasts or coupling the winds to other models.

The improved coastal winds can be attributed to how COAMPS computes surface roughness values. The 0.01 deg USGS data are averaged within each grid box, and in regions of sharply contrasting surface characteristics, roughness length may either be too low (such as along the narrow Mississippi River delta surrounded by water), or the transition may be too gradual (such as along the Mississippi Coast; see Figs. 6 and 7 for a comparison). The difference between grid-average surface roughnesses is shown in Fig. 8, indicating that coastal values can differ up to 35 cm. These differences are plotted for each of the 22 observation sites in Fig. 9, as are the mean wind biases at those stations. As can be seen, the biases are negatively proportional to the difference in model surface roughness values.

As may be expected, these roughness value differences also impact the 9- and 27-km wind direction. In this analysis, a "hit-miss" variation of a binary skill score is used for wind direction (BSS_{wdir}):

$$BSS_{wdir} = \frac{NWDIR_{9km} - NWDIR_{27km}}{N - NWDIR_{27km}} \times 100\%$$

where $NWDIR_{9km}$ is the number of correct 9-km forecasts within 30 deg, $NWDIR_{27km}$ is the number of correct 27-km forecasts within 30 deg, and N is the number of observations for a forecast hour. The threshold of 30 degree is chosen because this value equals the desired forecast accuracy for DOD purposes (Cox et al. 1998). Using a 30-deg threshold, there are 30-50% more "correct" wind direction forecasts of 9-km COAMPS versus 27-km COAMPS. (not shown). Unlike wind speed, these improvements also occur inland, as well as offshore east of coastal Louisiana. When using a high-precision 10-deg threshold, the number of improved 9-km forecasts is 10-30%, with a few areas of degradation (not shown). When these cases are stratified by wind speed, it is observed that most of these improvements occur when wind speed is less than 10 ms^{-1}.

Additional December 2000 results of the COAMPS wind evaluation, as well as other model variables such as temperature, surface fluxes, etc., will be presented at the conference. Furthermore, an evaluation of NGLI COAMPS runs for Summer 2001 are also being conducted, and will be shown at the conference.

References

Arya, S.P., 1988: *Introduction to Micrometeorology.* Academic Press, 307 pp.

Blumberg, A.F., Q Ahsan, H. Li, I.D. Kaluarachchi, and J.K. Lewis, 2001: Towards the Development of a Comprehensive Circulation, Sediment Transport, Wave, and Water Quality Modeling System for the Mississippi Sound/Bight. Technical Report USM0020, 100 pp. Available from: HydroQual, Inc., One Lethbridge Plaza, Mahwah, NJ 07430.

Blumberg, A.F., A. L. Khan, and J. P. St. John, 1999: Three-dimensional hydrodynamic model of New York Harbor region, *J. Hyd. Eng.*, **125(8)**, 799-816.

Blumberg, A.F., and G. L. Mellor, 1987: A Description of a Three-Dimensional Coastal Ocean Circulation Model. In: *Three-Dimensional Coastal Ocean Models*, N. Heaps, Ed., American Geophys. Union, 1-16.

Booij, N., R.C. Ris, and L.H. Holthuijsen, 1999: A third-generation wave model for coastal regions, Part I: Model description and validation. *J. Geo. Res. C4*, **104**, 7649-7666.

Cox, R., B.L. Bauer, and T.A. Smith, 1998: A mesoscale model intercomparison. *Bull. of Amer. Met. Soc.*, **79**, 265-283.

Gallus, W.A. Jr., 1999: Eta simulations of three extreme precipitation events: Sensitivity to resolution and convective parameterization. *Wea. Forecasting.* **14**, 405-426.

Hodur, R.M., 1997: The Naval research laboratory's Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS). *Mon. Wea. Rev.*, **125**, 1414-1430.

Houston, S.H., and M.D. Powell, 1997: Surface wind fields in hurricanes. Proceedings, Third International Symposium, Waves '97, Virginia Beach, VA, November 3-7, 1997. American Society of Civil Engineers (ASCE), 1391-1399.

Kain, J.S., and J.M. Fritsch, 1990: A one-dimensional entraining/detraining plume model and its application in convective parameterization. *J. Atmos. Sci.*, **47**, 2784-2802.

Kain, J.S., 1993: Convective parameterization for mesoscale models: The Kain-Fritsch scheme. The representation of cumulus parameterization in numerical models. Meteor. Monogr. No. 24., *Amer. Meteor. Soc.*, 165-170.

Mellor, G. L., 1998: Users guide for a three-dimensional, primitive equation, numerical ocean model. Prog. In Atmos. and Ocean. Sci, Princeton University, 41 pp. Available at http://www.aos.princeton.edu/WWWPUBLIC/htdocs.pom/ .

Pielke, R.A., 1984: *Mesoscale Meteorological Modeling.* Academic Press, 612 pp.

Ris, R.C., N. Booij, and L.H. Holthuijsen, 1999: A third-generation wave model for coastal regions, Part II: Verification. *J. Geo. Res. C4*, **104**, 7667-7681.

Rutledge, S.A., and P.V. Hobbs, 1983: The mesoscale and microscale structure of organization of clouds and precipitation in midlatitude cyclones. VIII: A model for the "seeder-feeder" process in warm-frontal rainbands. *J. Atmos. Sci.*, **40**, 1185-1206.

Weisman, M.L., W.C. Skamarock, and J.B. Klemp, 1997: The resolution dependence of explicitly modeled convective systems. *Mon. Wea. Rev.*, **125**, 527-548.

Wilks, D.S., 1995: *Statistical Methods in the Atmospheric Sciences.* Academic Press, 467 pp.
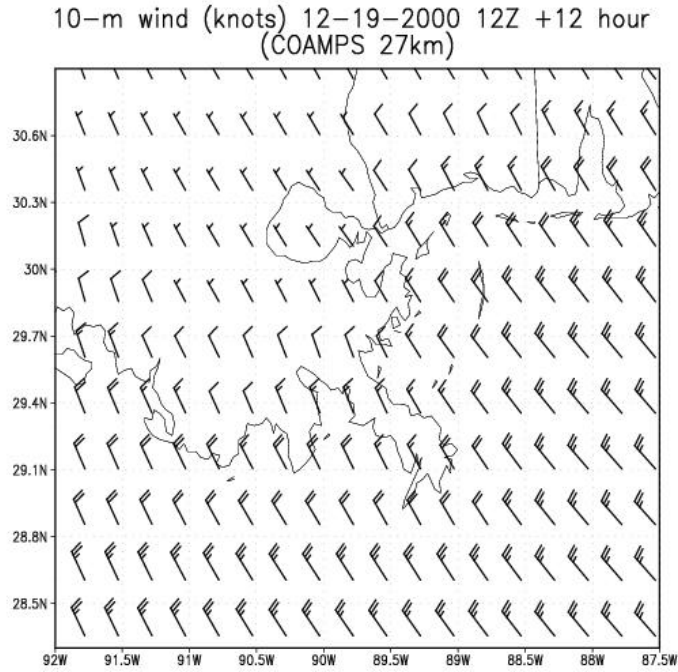
Figure 1. 10-m COAMPS winds (in knots) 12 h into the simulation for 19 December 2001, initialized at 12Z, with a grid spacing of 27 km for the NGLI region.
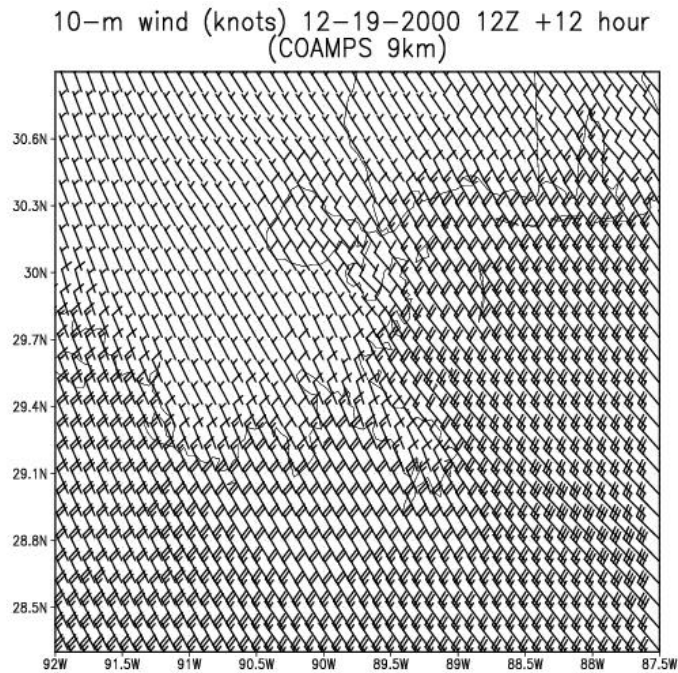
Figure 2. Same as Fig. 1, but at 9-km grid spacing instead in the NGLI region (nested inside a 27-km COAMPS mother domain).
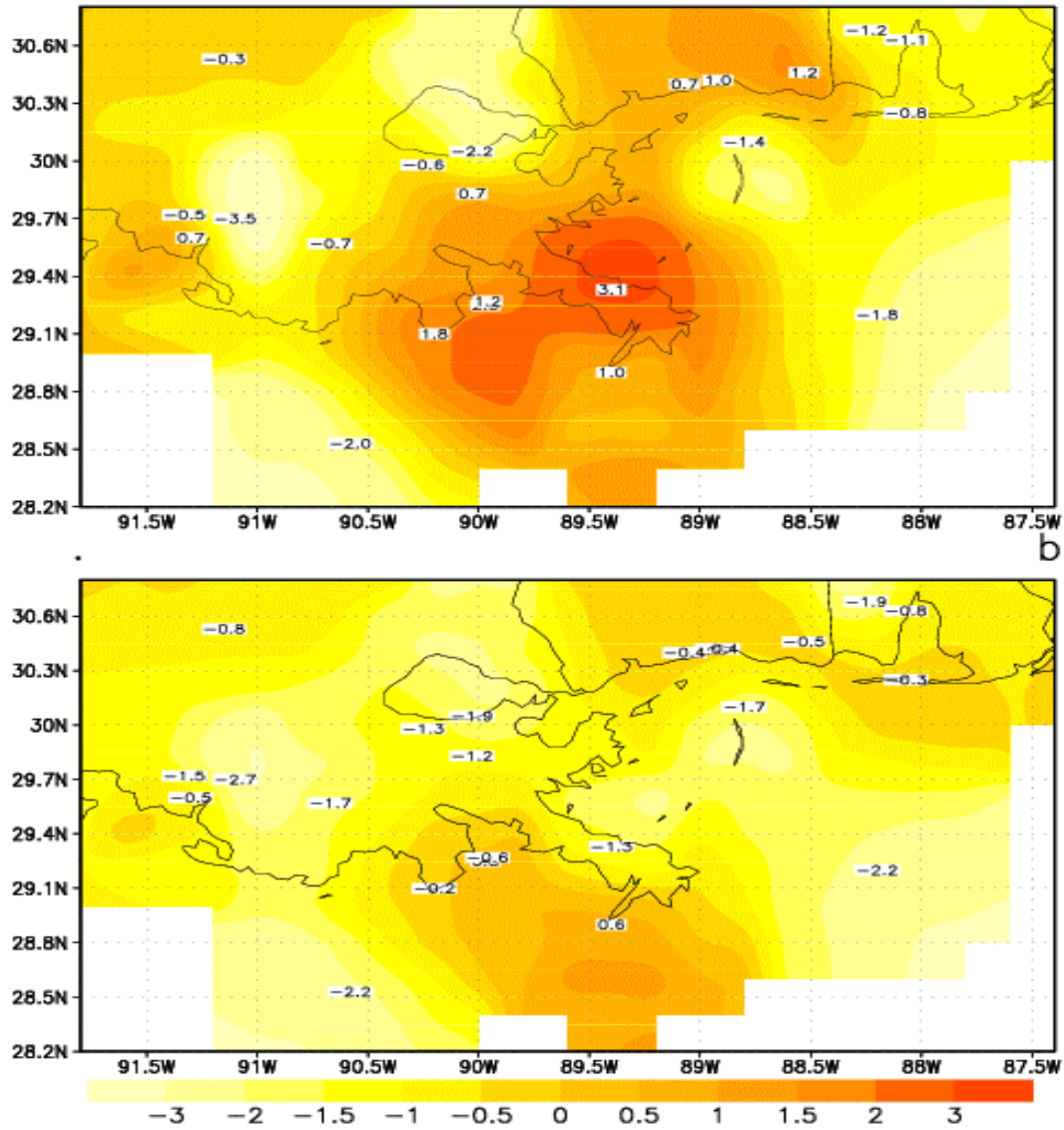
27-km and 9-km COAMPS speed bias (ms^{-1})

Figure 3. Geographical distribution of wind speed bias (ms^{-1}) of 27-km COAMPS (top figure) and 9-km COAMPS (bottom figure) for all 12 model simulation. The bias calculation includes 12-, 18-, 24-, 30-, 36-, 42-, and 48-h model times. The bias is computed as model minus observations.

Skill Score (%) of 27-km versus 9-km COAMPS in terms of wind speed mean absolute error
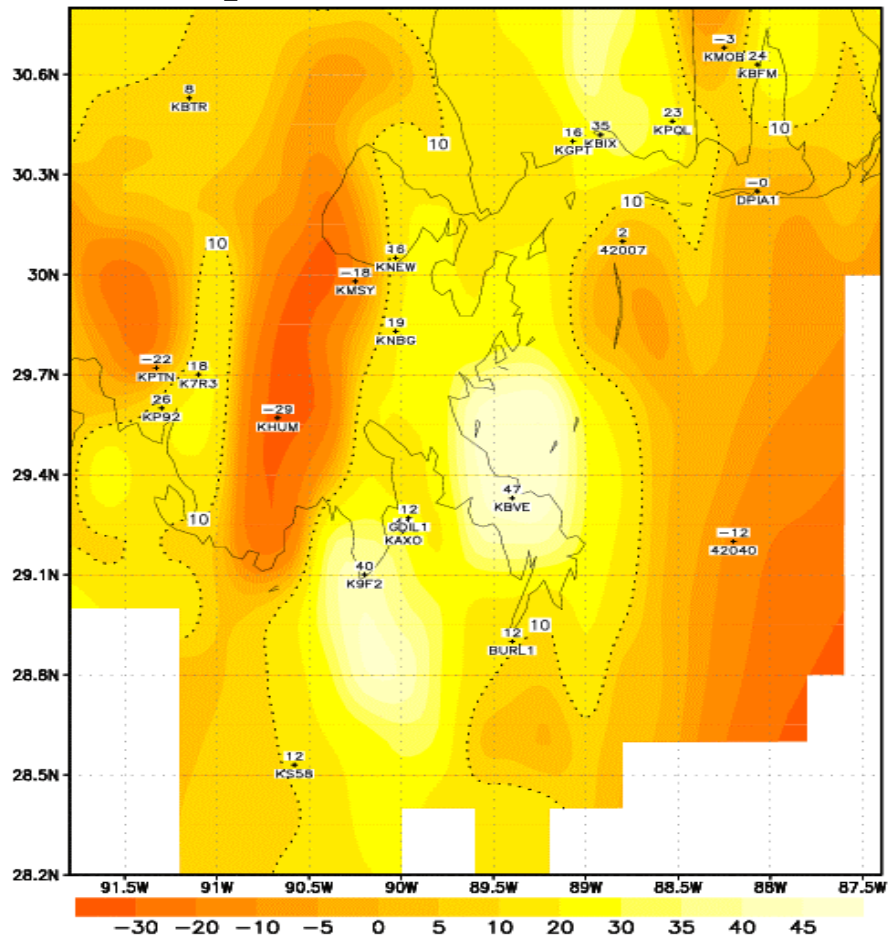
Figure 4. Same as Fig. 3, but for geographical distribution of Skill Score (%) of 9-km COAMPS versus 27-km COAMPS in terms of wind speed mean absolute error. Positive values indicate the percentage improvement of the 9-km runs versus 27-km runs.
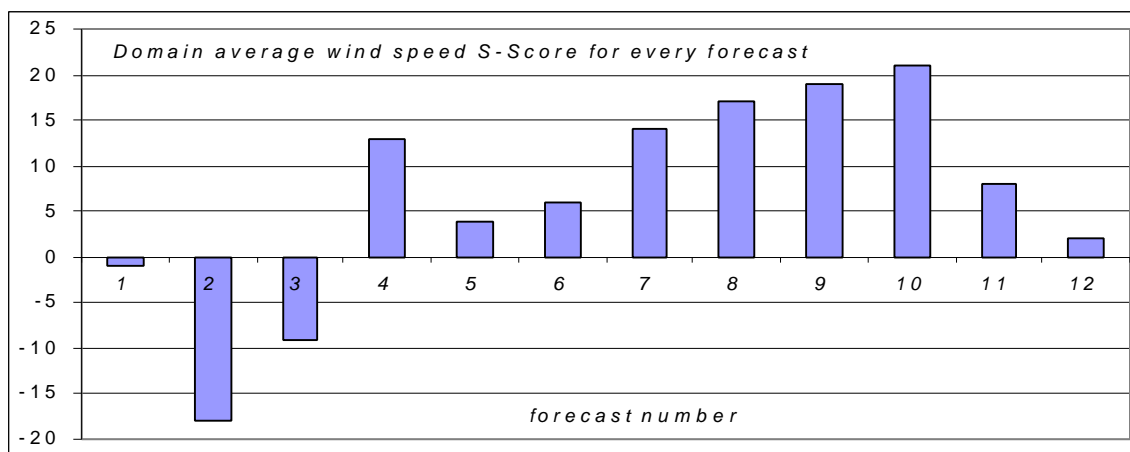

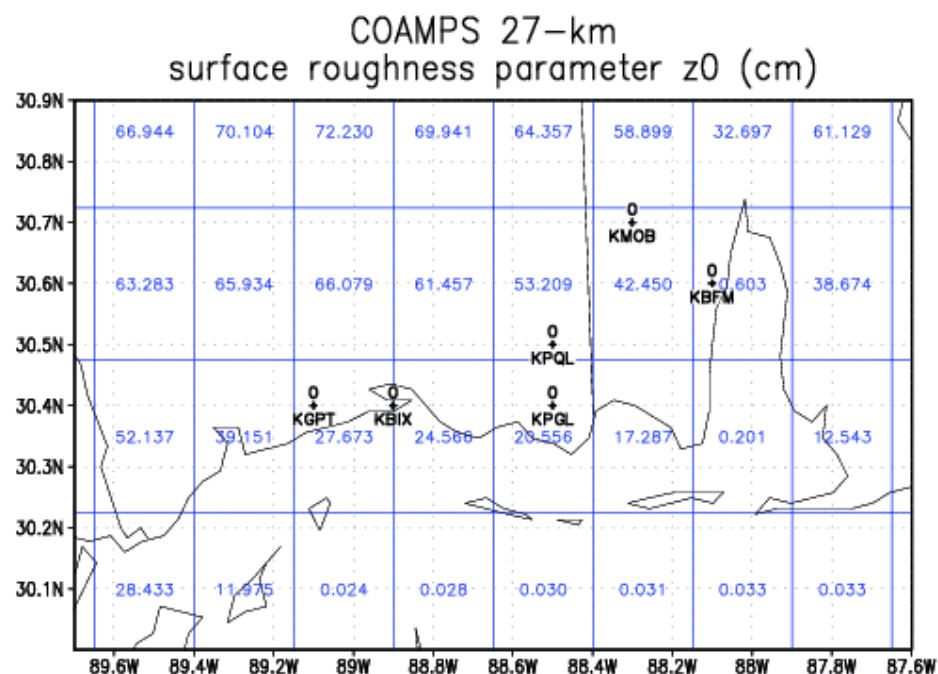**Figure 5. Skill scores as discussed in Fig. 4, but for each simulation.**

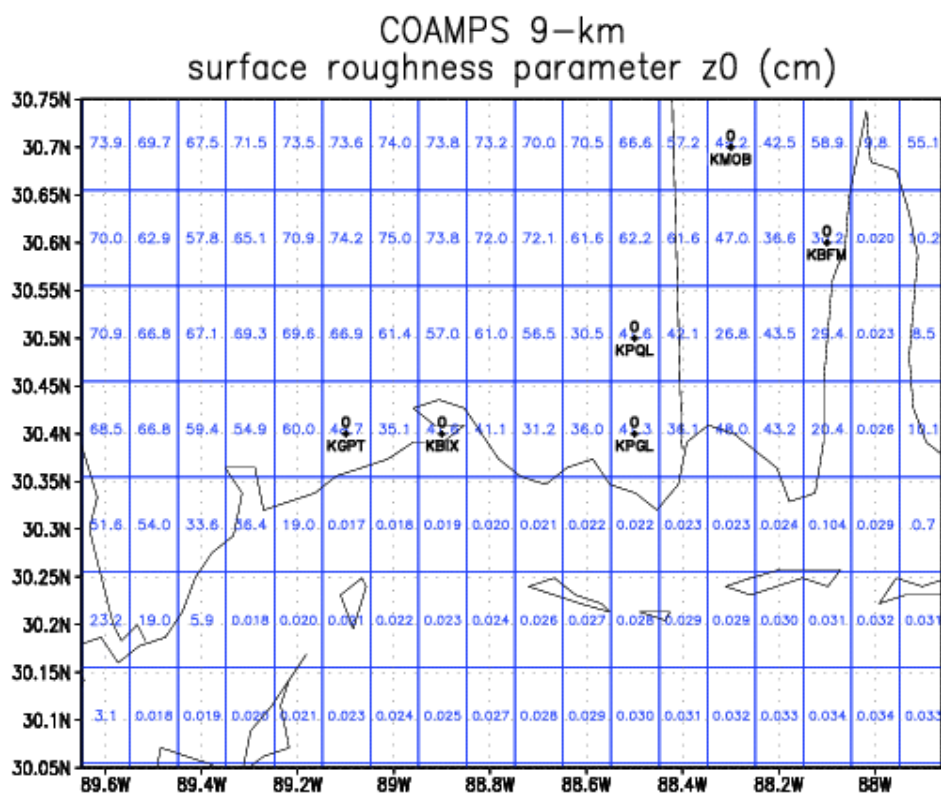**Figure 6. Grid-averaged surface roughness values for COAMPS 27-km grid along Mississippi Coast.**

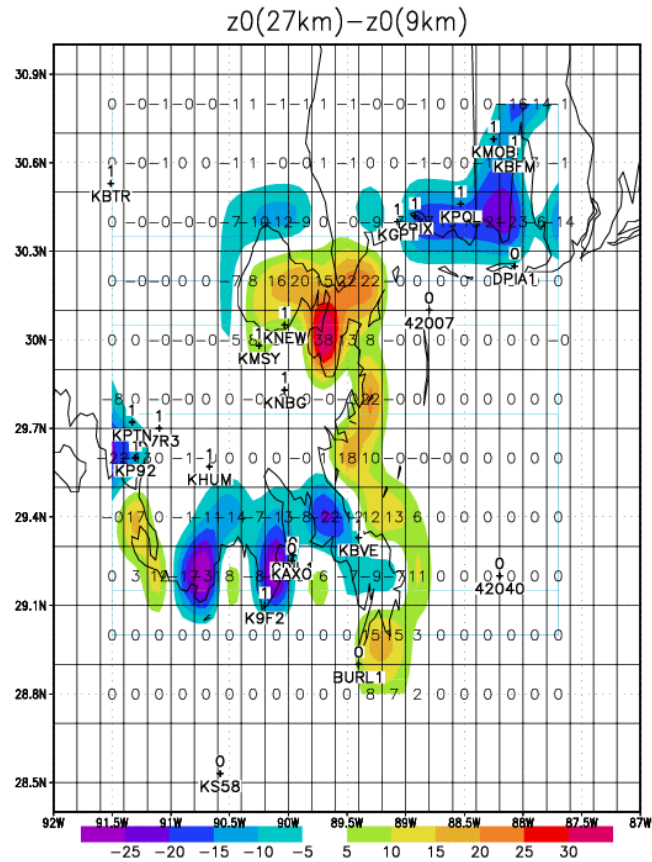**Figure 7. As in Fig. 6, but for 9-km COAMPS.**

Figure 8. The difference between grid-averaged surface roughness values for 9-km and 27-km COAMPS in the NGLI region.
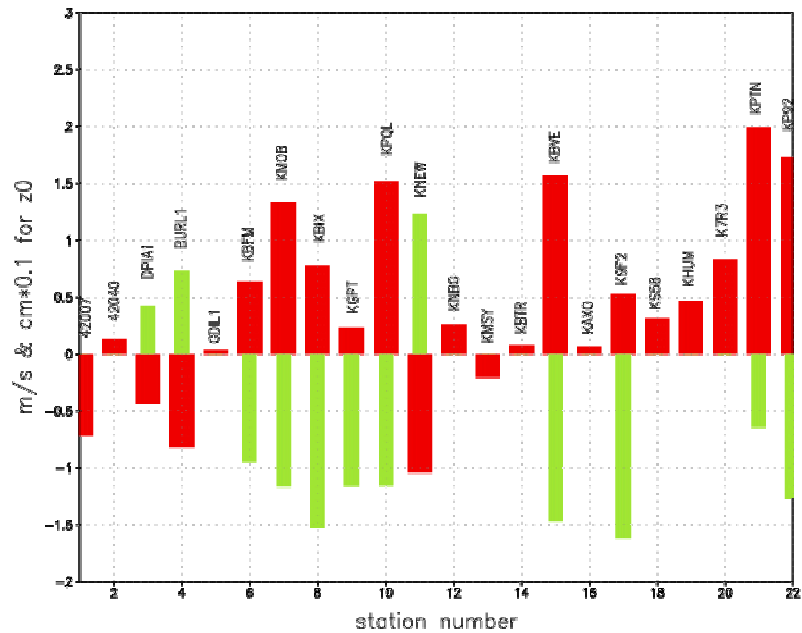

Figure 9. 27-km mean wind speed biases (ms^{-1}), and differences in 27-km and 9-km grid-averaged surface roughness length (cm*0.1) at the 22 observation stations.