

Evaluation and Improvement of High-resolution Mesoscale Models on Boundary Layer Simulations Using Ground-based Observations

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LONG-TERM GOAL

The long-term goal of the proposed work is to improve the physical parameterizations and wind forecast from high-resolution COAMPS. This is done through analyses of a large amount of data from the two dense measurement network located on the two Air Force bases and through testing and evaluation of COAMPS simulations.

OBJECTIVES

The objectives of this year's work were to obtain data from the relevant agencies, to make initial analyses of the datasets, to establish COAMPS simulations centered at the measurement sites.

APPROACH

This project involves extensive data handling and analyses and model testing using high-resolution COAMPS. Our general approach is to identify model issues through data analyses and model-observation inter-comparison. Improvements of model physics should be a result of these analyses and testing. Eventually, improved model physics will be tested in COAMPS and evaluated against the observations. Within this project, we will also investigate methods for objective model evaluation, particularly for high-resolution mesoscale models.

Investigators in this project include Dr. Qing Wang (PI) and Dr. Kostas Rados who is a visiting professor at NPS supported by this project. Lt. Col. Karl Pfeiffer (USAF), military faculty at Information Sciences Department at NPS, assisted in obtaining data and data collection information from various AF units. Collaboration efforts with Dr. Melinda Peng at NRL is an important part of this project which include COAMPS physical parameterization development and testing and identifying the path for eventual transition of the results to operational COAMPS.

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WORK COMPLETED

1. Acquiring data from its archive sources and gathering data collection information were more difficult and time consuming than we anticipated. We were able to obtain data from 12 measurement towers on Cape Canaveral Air Force Station in 2008. Initial data processing was made on this dataset that included data accessing, consolidation of data collection and site information, and initial data quality checking.
2. The tower measured meteorological measurements from all 12 towers were analyzed to identify cases for in-depth analyses. We selected a high-wind case associated with tropical storm Fay that made a record four landfalls in Florida and was measured at the measurement site.
3. In-depth analyses of surface layer vertical profiles and surface layer properties throughout 2008 and particularly during tropical storm Fay were made using all available data. Among other variables, surface roughness heights were examined using two levels of surface layer measurements.
4. We setup COAMPS simulations of tropical storm Fay before and during its landfalls in Florida using the latest version of operational COAMPS. This initial test simulation revealed strength and weakness of current COAMPS in simulating the tropical storm and will be the bases of model evaluation.

RESULTS

Passage of tropical storm Fay over the Cape Canaveral measurement region: To illustrate the measurements from the many towers at Cape Canaveral Air Force Station, Fig. 1 shows an example of the temporal variations of pressure, near surface temperature, wind speed and wind direction between August 18 and 24, 2008 at tower 0003 located at the tip of Cape Canaveral on the coastline. Measurements on tower 0003 include two levels of temperature and wind sampling at 3.7 and 16.5 m above the local surface. These two levels of measurements allow us to calculate surface roughness length (z_0) and surface layer frictional velocity (u_*), which are also shown Fig. 1.

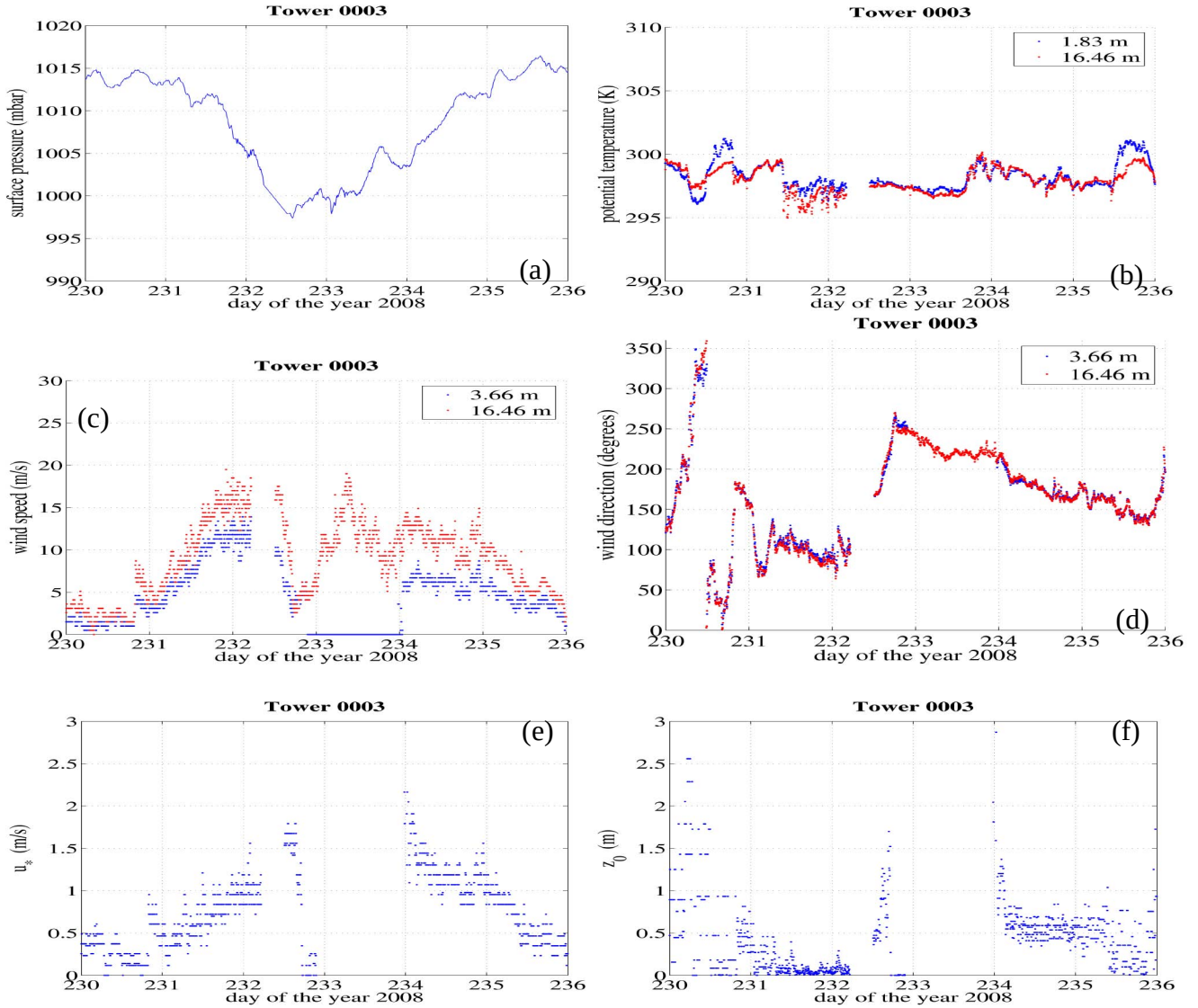


Figure 1. Variation of (a) surface pressure (mb); (b) potential temperature (K); (c) wind speed (ms^{-1}); (d) wind direction (deg); (e) surface layer frictional velocity (u_*), and (f) surface roughness, z_0 before and after the landfalls of tropical storm Fay.

Figure 1 shows that the lowest surface pressure at tower 0003 occurred at around midday of day 232 (August 20). At about the same time, wind speed reached its minimum at both levels and wind direction changed rapidly from easterly (90°) to westerly (260°). It is clearly seen that the surface roughness length changed significantly during the several day period (Fig. 1f). Of particular interest is the comparison of surface roughness length on day 231 (Aug 19) and day 234 (Aug 22). On Aug 19, wind was predominantly easterly from the ocean, while on Aug 22, the mean wind direction was southwest with significant land surface influence from upwind (Fig. 1d). Although the average wind speed on Aug. 19 is slightly higher than that on Aug. 22, the surface roughness length on Aug. 19 is much smaller compared to that on Aug. 22. It is evident that the surface roughness length is a strong

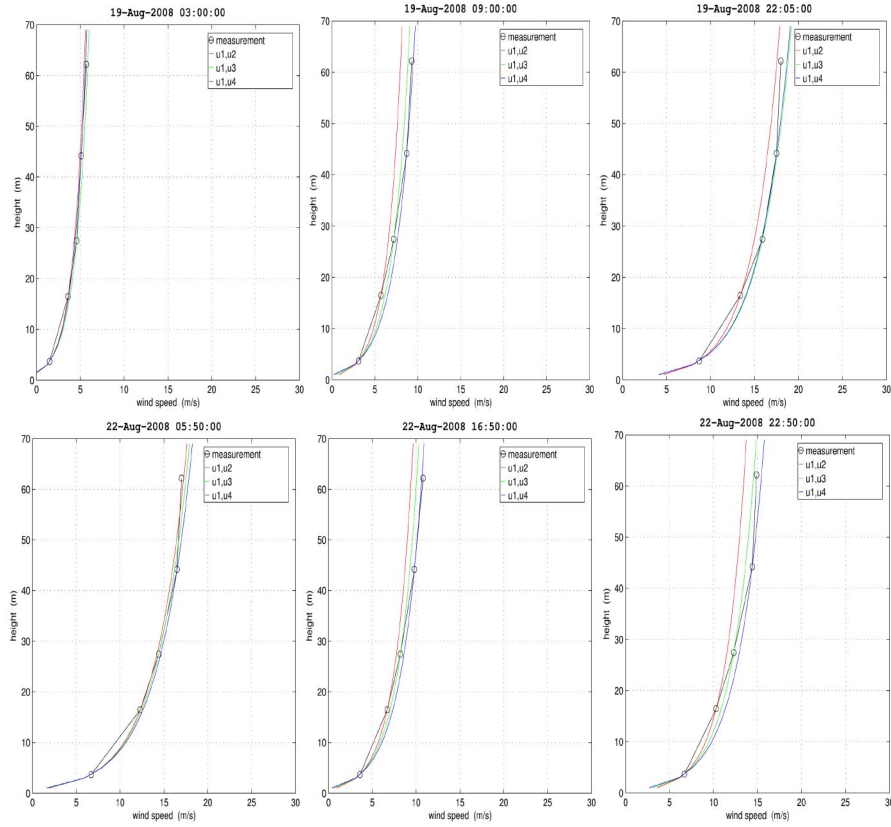


Figure 2. Vertical profiles of wind speed before (Aug. 19) and after (Aug. 22) the storm center passes the tower site. The corresponding line plots (no symbols) are log profiles fitted to two levels of measured values. The U1, U2, U3, and U4 denote measurements made at various levels.

function of wind direction under inhomogeneous surface conditions. However, the roughness length in COAMPS is a constant value unrelated to upwind conditions. The results shown here is supportive to the idea that surface roughness is a surface layer dynamic quantities and can not be simply specified based on land surface properties. The impact of the fixed value roughness in the forecast model is a subject to be investigated as part of the FY10 efforts.

Figure 2 shows the evolution of vertical profiles of vertical wind speed profiles during the landfall of Fay on Aug 19 and Aug 22 from tower 0020, a high tower with four levels of wind measurements. Tower 0020 is about 17 km north of tower 0003 and is also situated on the coastline. Because of the easterly wind direction on Aug. 19, the wind profiles represent the marine surface layer property from upwind over the water, while those from Aug. 22 should have dominant land surface effects. In both situations, however, the log wind profiles seem to be fairly good fit to the observed vertical wind profiles, although one should keep in mind that the range of wind speed in this case is weak compared to that resulting from a strong hurricane.

Variations of surface roughness length with wind speed and direction: To further examine the variability of surface roughness length with wind speed and wind direction, we examined measurements from Tower 0003 using data from the entire year of 2008. Sixteen equal sectors of wind direction were used to obtain a composite of roughness length variation with wind speed in each wind

direction sector of 22.5° azimuth angle. Results from the easterly and southwesterly wind sectors are shown in Figure 3. These results from the two wind sectors seem to suggest higher z_0 at low wind conditions. Similar results in the low wind conditions are also seen from other wind sectors. However, this results should be investigated carefully as the calculated z_0 at low wind has significant variability as indicated by the large standard deviation (error bars) shown in Fig. 3. The measurement quality at low wind conditions should be further examined to reduce uncertainties associated with flow distortion by the tower itself, instrument errors, and the effects of the limited decimal digits in the data archive. At moderate winds up to about 20 ms^{-1} , roughness length in both the ocean and land surface air show small variations with mean wind speed. However, z_0 from the upwind marine environment (easterly wind) is much smaller ($<0.1 \text{ m}$) than those from land surfaces ($\sim 1 \text{ m}$). In addition, z_0 variability (length of the error bars) within each wind speed bin in the moderate wind conditions is small in surface layers with marine or land surface origins. These results will be examined using data from other towers and possibly from the west coast location as part of the FY10 efforts.

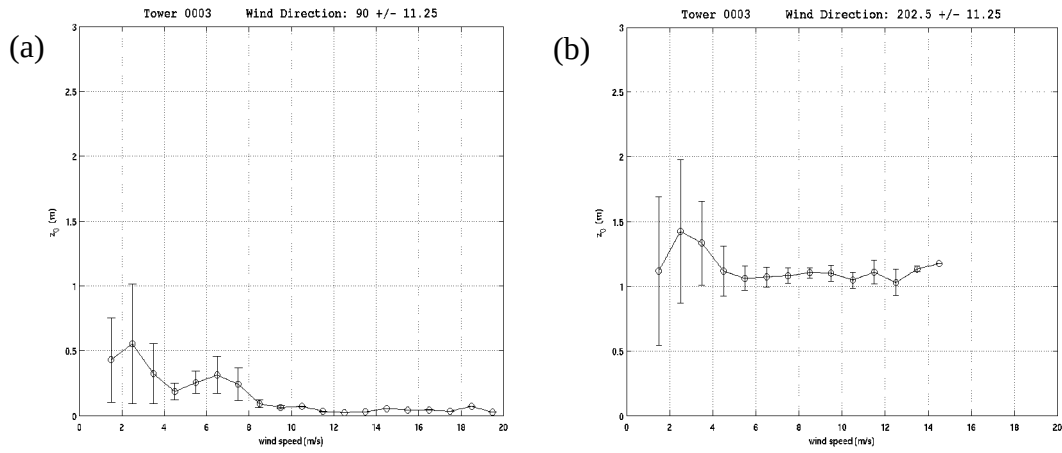


Figure 3. Variations of surface roughness with mean wind speed calculated using Monin-Obukhov similarity and two levels of measurements from Tower 0003 on the tip of Caper Canaveral. (a) easterly wind direction centered at 90° wind direction; (b) southwesterly wind direction centered at 202.5° .

COAMPS simulations of tropical storm Fay: COAMPS simulations were made to capture the evolution of tropical storm Fay between Aug. 16 and Aug. 24, 2008. For each day, a COAMPS forecast of 48 hours were made that was initialized from the NOGAPS fields and was run with data assimilation. Figure 4 shows the forecast storm track from each day's simulation at 6 hour intervals. The red solid line is the observed storm track obtained from the NOAA storm report on Fay. The COAMPS results revealed some significant deviation of the storm track in some of the simulations (e.g., simulations of Aug. 18 and 21), while the track predictions on other days (e.g. Aug. 17, and 22) are rather consistent with observations. We will examine the model-observation differences taking into consideration of the track and timing differences of the modeled storm and attempt to identify more appropriate methods for model evaluations for phenomena with a relatively well-defined spatial structure such as hurricanes and tropical storms.

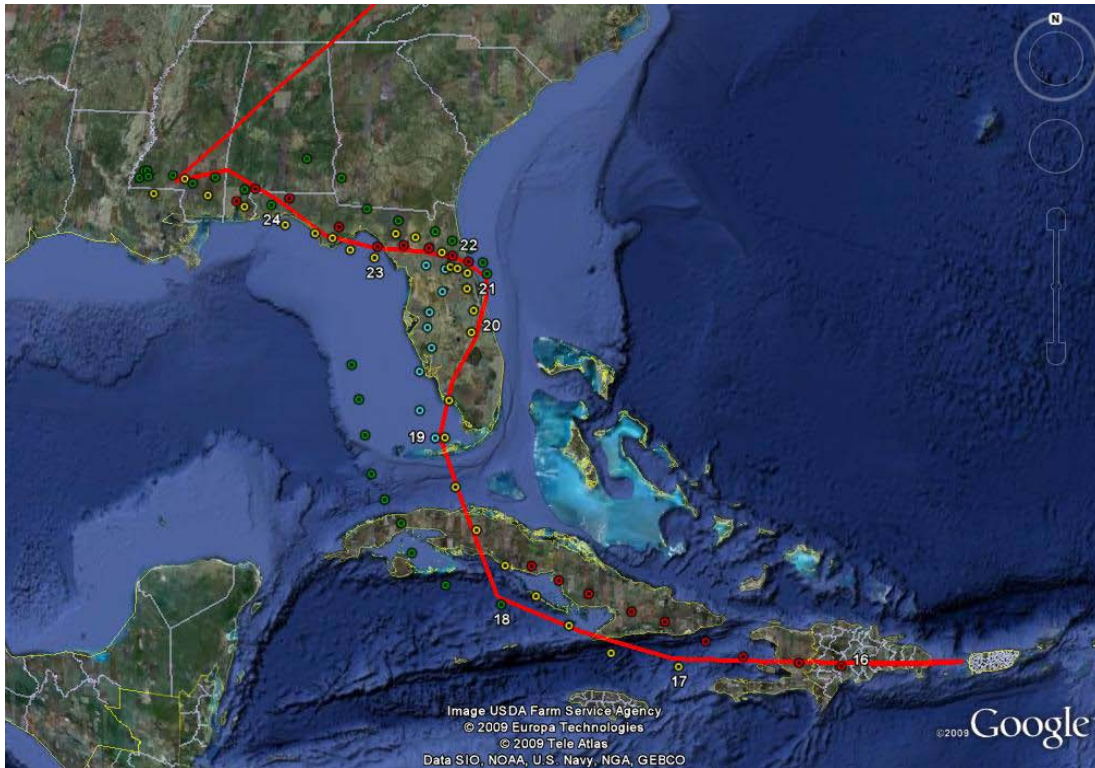


Figure 4. Observed (red line) and predicted storm track of tropical storm Fay in August 2008. Predicted storm tracks from each simulation are shown in 6 hour interval. Since 48-hour forecast were made each day, the simulated storm track is plotted for each day's forecast starting at the beginning of the day denoted by the points on the observed storm track and label with the date number of August.

IMPACT/APPLICATIONS

Surface inhomogeneity is a significant feature of the coastal region and in many regions of the world. A crucial issue of high-resolution numerical models in inhomogeneous conditions is the specification of the surface roughness length, which is treated as a static quantity in the model. Our initial study has suggested that the current method of obtaining surface roughness length is inappropriate and may lead to significant error of forecast and future improvements are needed. In addition, using large amount of measurements from two dense measurement network and Air Force bases, we will also examine the appropriate method for high-resolution model evaluation, which is also an important current issue of forecast verification.

TRANSITIONS

We have set of goal to transition findings from this research to operational forecast COAMPS through close collaboration between NPS and NRL Monterey.