COMPARISON OF ARW AND NMM SIMULATIONS
OF LOW-LEVEL METEOROLOGICAL CONDITIONS IN CALIFORNIA’S CENTRAL VALLEY

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1. INTRODUCTION

The WRF-ARW (ARW) model has become popular for various applications in the air-quality community, particularly because of the option in the WRF-ARW model that allows “online” coupling of meteorology and chemistry. Recently, NCEP has also launched operational air quality forecasts in which the WRF-NMM (NMM) model is used to provide predicted meteorological conditions to a chemistry model.

Over the past few years, effort has been undertaken at NOAA/Earth System Research Laboratory to evaluate the performance of WRF-ARW and WRF-NMM in simulating low-level wind flows that control the transport and dispersion of pollutants in the Central Valley (CV) of California. The ongoing evaluation is focused primarily on the following low-level flows (see, e.g., Bao et al. 2007):

1. the incoming low-level marine air flow through the Carquinez Strait into the Sacramento River delta,
2. the diurnal cycle of upslope/downslope flows,
3. the up- and down-valley flow in the Sacramento Valley (SV),
4. the nocturnal low-level jet in the San Joaquin Valley (SJV), and
5. the orographically induced mesoscale eddies (the Fresno and Schultz eddies).

This paper focuses on two primary results from the evaluation. We first discuss a few difficulties with the model setup for both ARW and NMM, and then we discuss a comparison of the low-level meteorological conditions simulated by ARW and NMM with the observations taken in the Central Valley and the San Francisco Bay Area of California for a high surface ozone episode.

2. MODEL CONFIGURATIONS

Both the ARW and NMM version 2.2 were run for a domain covering all of California and at 2 resolutions: 12-km and 4-km, although only the 4-km simulations are discussed here. The ARW grid mesh is approximately the same size as the NMM grid mesh. Given the fact that the ARW and NMM models use different map projections and grid staggering, it is difficult to make the ARW grid coverage identical to the NMM coverage. Both the ARW and NMM models have 51 levels with the lowest model level about 30 m above the surface and 16 levels below 2 km. Boundary and initial conditions for both models are obtained by the WRF Preprocessing System (WPS) and the 6-hourly 40 km NCEP Eta analysis. The simulations are initialized at 12 UTC 29 July, and are run for 120 hours, ending at 12 UTC 3 August 2000.

In this study, we chose the same physics options for both the ARW and NMM simulations. Both models used the Mellor-Yamada-Janjic PBL and the Janjic surface layer schemes along with the NMM land surface model (LSM), and the GFDL short-wave and long-wave radiation parameterizations. The Ferrier microphysics scheme,
and in some of the simulations, the Betts-Miller-Janjic cumulus scheme were used. The ARW simulations were run with a 16-s time step and the NMM simulations were run with an 8-s time step. Additionally, there were differences in the frequency in which the physics parameterizations were called. While both models used the GFDL radiation schemes, different call frequencies were used in the two models: every 60 minutes for the NMM model and 10 minutes for the ARW model. The ARW simulations called the boundary layer physics every time step (bldt=0) and in the simulations that used the cumulus scheme, the cumulus physics was called every time step (cudt=0). In NMM, nphs, and in the simulations that used the cumulus scheme, ncnvc were both set to 18.

3. RESULTS

It is found in this study that a set of vertical grid and physics configurations that work well in the ARW model may not be suitable for the NMM model. It is not straightforward task to set up the NMM model and compare its performance with the ARW model. A few iterations are taken to ensure that both the models are set up as consistently as possible so that the comparisons of the two models are meaningful. It is found that the NMM simulation that is in the best agreement with observations is the one that uses the set of vertical grid and physics configurations recommended by our colleagues at NCEP. For the comparison to be as fair as possible, the ARW model uses the same vertical configuration as in the NMM model. The 10-m wind, 2-m temperature and downward solar radiation from the two model simulations are averaged over 17 observational sites in Central Valley and compared with observations (Fig. 1). Overall, the winds from the NMM model are in better agreement with those from the ARW model, while the opposite is true for the 2-m temperature. The comparisons of the downward solar radiation indicate that the ARW model, in general, is more cloudy in the early morning but less cloudy in the afternoon than the NMM model, but the downward solar radiation from the NMM model is slightly better than the ARW model.

An interesting finding is that at 4-km horizontal resolution, the NMM model requires the use of the Betts-Miller-Janjic cumulus scheme along with the Ferrier microphysics scheme to have the best simulation using the WPS initialization. Figure 2 shows comparisons of the NMM simulations with and without the use of the Betts-Miller-Janjic cumulus scheme, indicating that the differences between the two simulations are not negligible. On the other hand, the differences between the two ARW simulations with and without the cumulus scheme are small (Fig. 3).

4. CONCLUSIONS

This study is the first attempt to compare the ARW and NMM models in the same WRF framework for simulating the low-level winds in California’s Central Valley. Both the ARW and NMM simulated low-level wind are compared with surface and wind profiler observations. It is found in this study that special attention is required to the setup of both physics and vertical grid configurations. For horizontal grid resolution of 4 km, if the WRF WPS initialization is used, the current version of the NMM model requires the use of a convective parameterization scheme in combination with the Ferrier microphysics scheme to suppress unrealistic convection along the west slope of Sierra Nevada.
Mountains, while there is no such need in the ARW model. In order for the 4-km NMM model to simulate the low-level winds that are comparable to the ARW’s simulation, the vertical resolution within the lowest 2 km needs to be coarser than the ARW’s. It is also found that the 4-km NMM is more sensitive to the small differences between the SI and WPS initialization. Further diagnosis is needed to understand the reasons behind the differences in the simulated low-level winds by the two models.

5. REFERENCES

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Figure 1: a) Comparison of the NMM (red lines), ARW (blue lines) and observed (black lines) 10-m wind speed (top panel), 10-m wind direction (second panel from top), 2-m air temperature (third panel from the top), and solar radiation (bottom panel) averaged over 17 profiler sites that are located within the CV. b) The bias of the NMM and ARW 10-m wind speed (top panel), 10-m wind direction (second panel from the top), 2-m air temperature (third panel from the top), and solar radiation (bottom panel) averaged over 17 profiler sites that are located within the CV.
Figure 2: a) Comparison of the 10-m wind speed (top panel), 10-m wind direction (second panel from the top), 2-m air temperature (third panel from the top), and solar radiation (bottom panel) averaged over 17 profiler sites that are located within the CV. Red lines are from the NMM simulation with the Betts-Miller-Janjic cumulus parameterization scheme, blue lines are from the NMM simulation without any cumulus parameterization scheme and black lines are the observations. b) The 10-m wind speed bias (top panel), 10-m wind direction bias (second panel from the top), 2-m air temperature bias (third panel from the top), and solar radiation bias (bottom panel) averaged over 17 profiler sites that are located within the CV. Red lines are the biases of the NMM simulation with the Betts-Miller-Janjic cumulus parameterization scheme and blue lines are the biases of the NMM simulation without any cumulus parameterization scheme.

Figure 3: The same as Fig. 2, but for the ARW simulations