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Numerical Modeling Study of Wind Flow for the Salt Lake City Region Using the Integrated WRF-Noah-UCM Model at Meso-Gamma Scale

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1. INTRODUCTION

In this numerical modeling study, the integrated WRF/Noah/Urban Canopy Model (UCM) was applied at the meso-gamma scale (with grid spacing of 500 m), to the complex urban environment over the Salt Lake City (SLC) region. In its first major attempt, the meteorological fields from the coupled WRF-Noah-UCM model were used to drive a Computational Fluid Dynamics (CFD)-urban model. The UCM used in the present study was originally developed and applied to perform validation of surface temperature and net radiation against observed data (Kusaka et al. 2001). Later they applied the model to study the nocturnal heat island (Kusaka et al. 2004). It is not uncommon that the numerical boundary layer models have been applied previously, to investigate the heat island circulations by many investigators, such as Estoque and Bhumralkar (1969), Delage and Taylor (1970), Bornstein (1975). Yoshikado (1992) examined the basic characteristics of daytime heat island circulation using a two-dimensional hydrostatic boundary layer model. Otte et al. (2004) implemented the urban canopy parameterization into the MM5 model to improve the meteorological fields in the urban boundary layer simulations. In this paper, we focus on the variations of fine-scale wind fields over a complex urban environment, which is critical input for air pollution and dispersion models.

In order to incorporate the effects of urban regions on the numerical simulations, we have introduced simple modifications of soil parameters and constants in the Noah LSM that has produced reasonable improvements in the performance of the model (Liu et al. 2005). With the current computer capacity, it may be impractical to use sufficiently fine-grid spacing in a mesoscale model, even with urban parameterization, to explicitly simulate the wind flows at the neighborhood scale in complex urban areas such as SLC, which also has a very complex topography. Recently we have coupled the UCM with Noah LSM and applied the coupled model to study the wind flow over the SLC region. In their study of predictability of low-level winds, Rife et al. (2004) describe the verification of a model based, low-level wind forecast for the SLC area during the 2002 Salt Lake City Winter Olympics. Their study demonstrated a positive relationship between local forcing and forecast skills.

The objectives of the study were to: 1) evaluate WRF capability to represent the evolution of wind fields over SLC, and 2) provide the meteorological fields as input to drive a Computational Fluid Dynamics (CFD)-based urban area transport and dispersion model (CFD-Urban), to reach its steady state.

2. NUMERICAL EXPERIMENTS AND OBSERVATIONAL DATA

We used observational data from the URBAN 2000 (Allwine, 2002) field experiment sponsored by the U.S. Department of Energy's Chemical and Biological National Security Program. During this experiment, sulfur hexafluoride (SF6) releases were carried out in the Salt Lake City (SLC) area in October 2000. The main objective of URBAN 2000 was to collect the tracer concentrations and meteorological observations in this urban area in order to evaluate the performance and subsequent development and improvement of the numerical atmospheric models. In the present study we used the data from the Intensive Operating Period (IOP) 10 of URBAN 2000 of 26 Oct. 2000 for the evaluation of the performance of these numerical models.

Two numerical simulations were performed: (1) with a simple urban model treatment WRF-Noah; and

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(2) with the WRF-Noah-UCM model. These integrated WRF/Noah/UCM and WRF-Noah models were applied to perform a 24-h simulation for 26 Oct. 2000. Five nested domains were employed. The topography of the 0.5 km domain is shown in Fig. 1. High-resolution (30-meter) urban land-use data, with detailed classifications for the SLC urban zones (low-intensity residential, high-intensity residential, and the industrial/commercial zone) was aggregated into the WRF nested Domain-5 with 500-m grid spacing (Fig. 2).

3. RESULTS AND DISCUSSIONS

We integrated the WRF-Noah and WRF-Noah-UCM models for 24 hours starting on 26 Oct. 2000 00Z. Fig. 1 shows the 5 nested domains of our numerical models simulation; the finer domain is at 500m with 154 points in the E-W direction and 250 points in the N-S direction. The enlarged domain 5 has marked observational sites (PNNL sites, Raging Waters and Green City Center), for which we show some comparisons and evaluations of model performances.

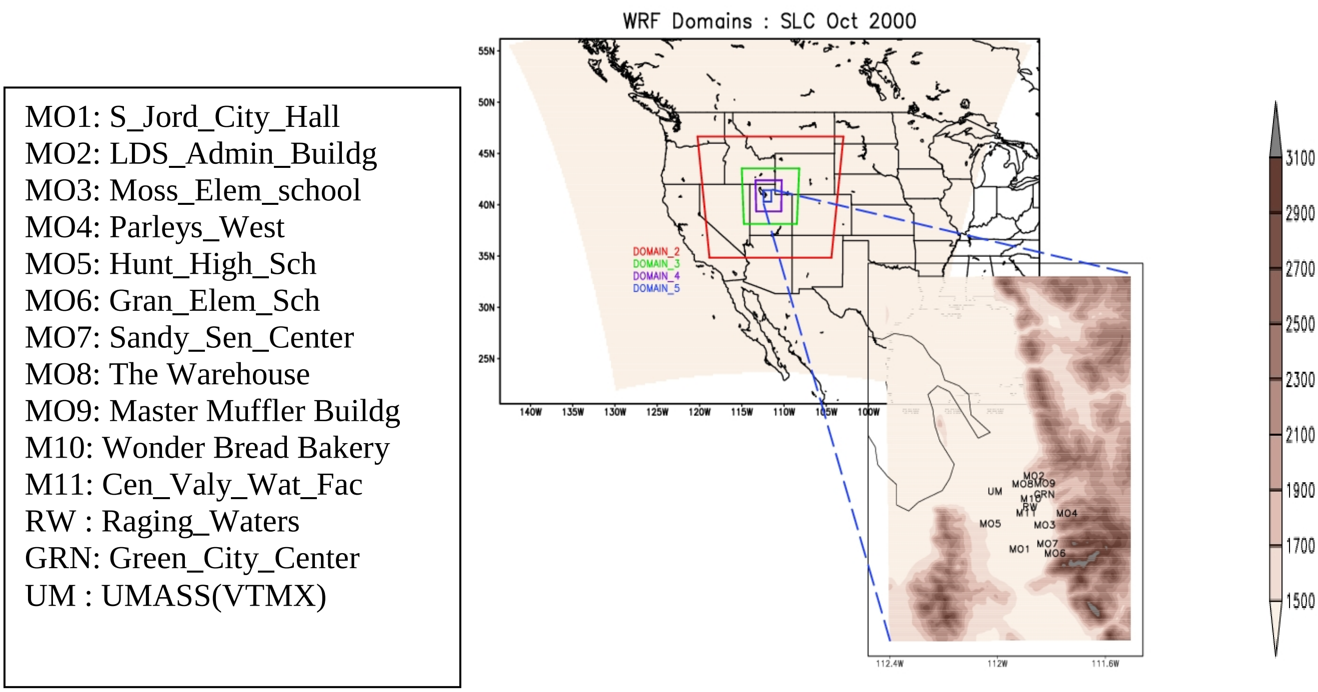


Figure 1: WRF domains, Observation sites and Terrain (0.5 Km)

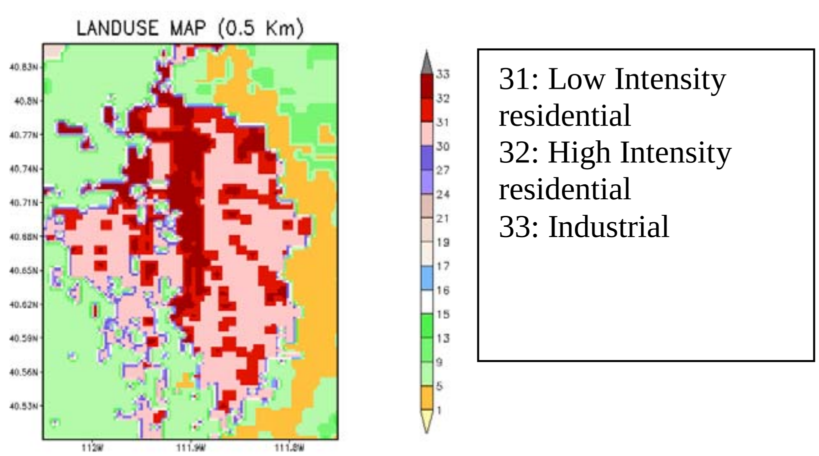
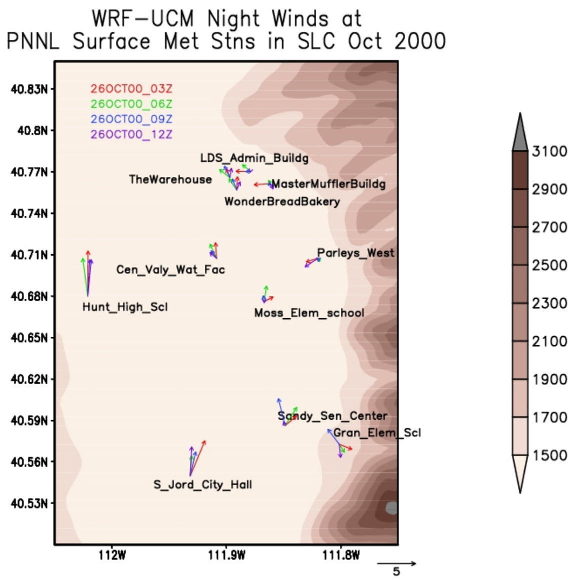
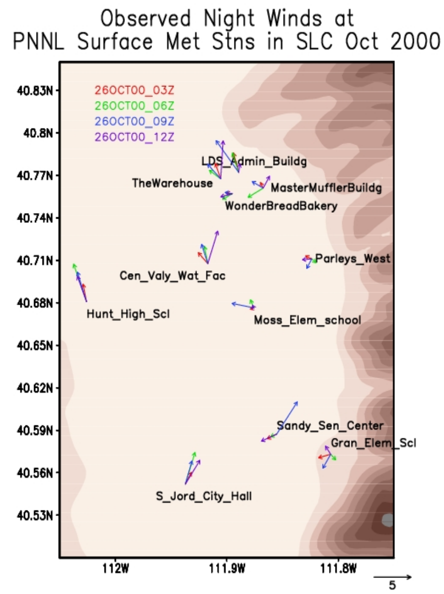


Figure 2: Land-use map of Salt Lake City at 0.5 km



(a)



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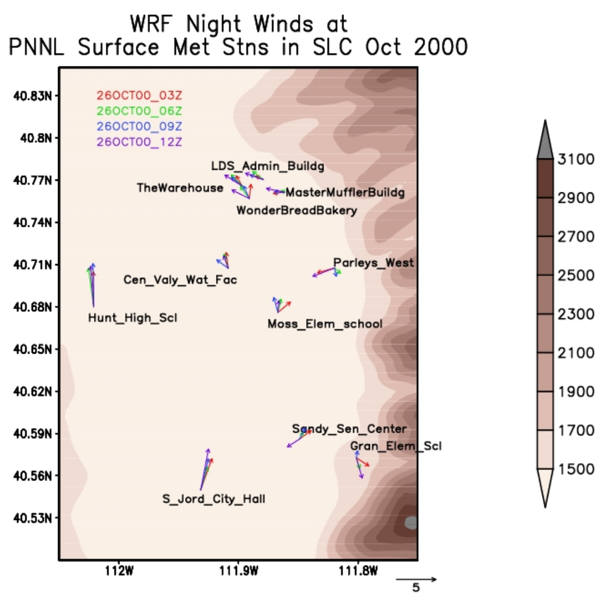
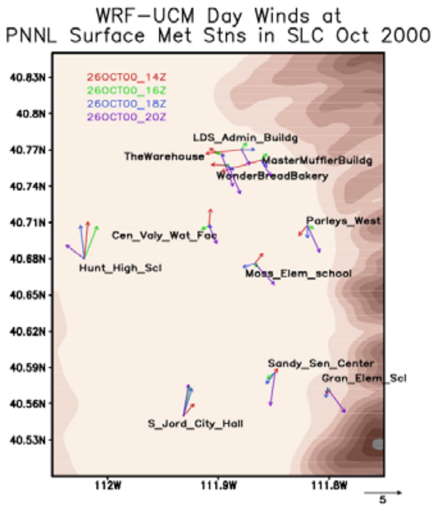
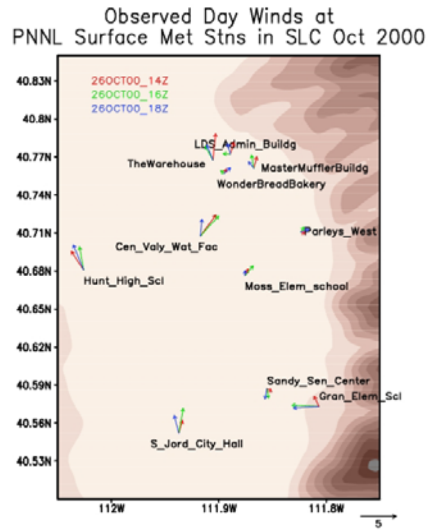


(c)

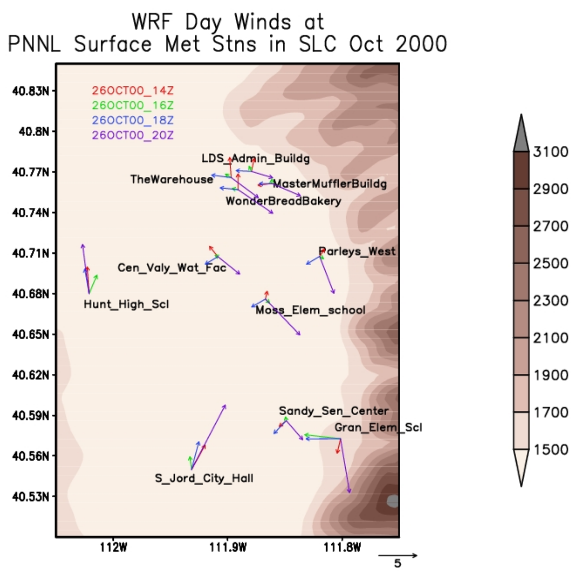
Figure 3: Variation of Wind at PNNL sites during nighttime (a) with WRF (Noah)-UCM (b) Observed (c) with WRF (Noah).



(a)



(b)



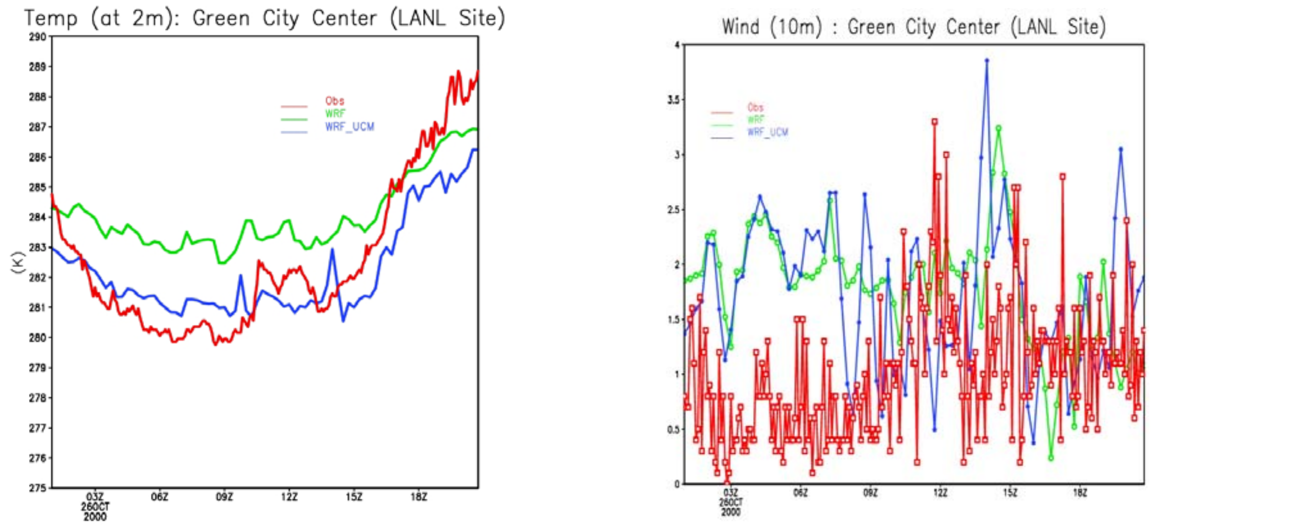
(c)

Figure 4: Same as fig 3 but for daytime

The temporal variation of wind during nighttime (3 hourly, Fig. 3) and daytime (2 hourly, Fig. 4) is shown for the WRF-Noah and WRF-Noah-UCM cases along with observations. Comparing the winds at the downtown sites (MO2: LDS Administrative building, MO8: The Warehouse, MO9: Wonder Bread bakery and M10: Master Muffler building) we notice that the WRF-UCM is able to capture the evolution of wind better than the WRF model, especially at MO2, MO8, MO9. The wind, in general, tends to rotate in anti-clockwise (03Z to 06Z) and then clockwise (later). WRF-UCM seems to capture this feature, although there seems to be a phase difference, which varies between sites. The WRF-Noah model, in general, shows an anti-clockwise rotation with time.

A similar comparison during daytime shows a good agreement at Hunt High School (MO1) and South Jordan City Hall (MO5) for WRF-Noah-UCM where we see that an evolution of wind is better compared with observations than with the WRF-Noah model.

For further comparisons, we use data from one of six meteorology stations deployed in downtown SLC from 1-27 October, 2000. Each station contained a 2-D Handar sonic anemometer and two thermistors. This station, Green (500), was mounted on a light pole in the parking lot between the City Center building and the Heber-Wells building. The diurnal variation of 2m temperature and wind speed at Green City Center for WRF-Noah, WRF-Noah-UCM is shown in Fig. 5.



(a) **(b)**

Figure 5: (a) 2-m air temperature and (b) 10-m wind speed at Green City Center (LANL site) Green: WRF-Noah, Blue: WRF-Noah-UCM, Red: Observed

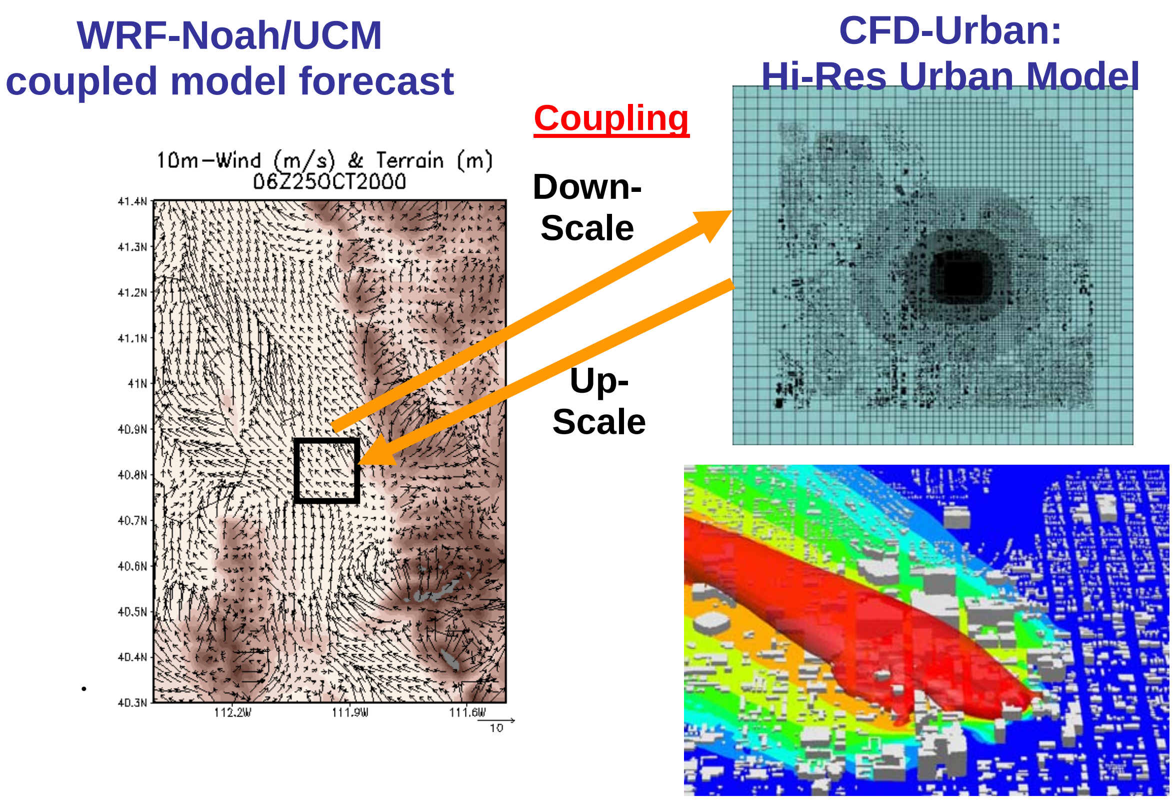


Figure 6: Illustration of WRF-Noah/UCM model deriving the CFD-urban model

It is found that WRF-Noah-UCM (shown in blue) is generally in good agreement with observations, although it does show a cold bias during the daytime. This result reiterates the importance of initialization of urban parameters which are quite sensitive to the performance of the coupled WRF-UCM model. The 10-m wind speed comparison shows that the WRF-Noah-UCM model shows more variability as compared to WRF-Noah model, although both models over-predicted the wind speed at Green City during nighttime. Fig. 6 is an illustration of the coupling of the WRF-Noah/UCM model with CFD-urban model winds. Preliminary results using the coupled WRF-Noah-UCM-CFD model will be presented at the conference.

CONCLUSIONS

Two high-resolution numerical integrations (with the grid spacing of 0.5 km for the finer domain) using coupled WRF-Noah and WRF-Noah-UCM models for the 26 Oct. 2000 case over the complex urban SLC region. For the evaluation of the model results, we used observational data available from the IOP 10 during the URBAN 2000 field experiment. We found that the coupled WRF-Noah-UCM model captured the evolution of temperature and winds better than the WRF-Noah model. Further comparisons with VTMX data are in progress and will be presented at the conference.

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