MM5-BASED MODELING AND MODEL OUTPUT STATISTICS FOR THE 2002 OLYMPIC WINTER GAMES

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1. INTRODUCTION

In February 2002, the Olympic Winter Games will be held in the Salt Lake City (SLC) metropolitan area and the nearby Wasatch Mountains. With as many as 100,000 spectators and athletes attending and competing daily at outdoor venues, accurate weather forecasts are critical for public safety and games logistics. For the first-time, Olympic weather support is being provided by a partnership between government, private sector, and academic meteorologists. Private-sector meteorologists will be responsible for forecasts at outdoor Olympic venues, the National Weather Service (NWS) will provide forecasts for security, transportation (ground and air) and public safety, and the University of Utah/National Oceanic and Atmospheric Administration Cooperative Institute for Regional Prediction (NOAA–CIRP) will run forecast support systems, including the NOAA–CIRP real-time MM5.

Mesoscale modeling activities for the 2002 Winter Olympics have involved providing twice-daily real-time model guidance to Olympic forecasters for more than three years prior to the games. This allows for (1) validation and hands-on use of the modeling system well in advance of the Olympics and (2) the development of MOS equations that provide point-specific forecasts for Olympic venues and other weather sensitive locations. Although the basic structure of the NOAA-CIRP real-time MM5 has remained intact during this period, it has undergone upgrades and improvements that will continue until just prior to the Olympics.

2. MODEL DESCRIPTION

The NOAA–CIRP real-time MM5 modeling system is based on the non-hydrostatic Penn State/NCAR MM5 Version 3 (Grell et al. 1995). Since July 1998, the model has been run with a 36-km outer nest covering the western United States and eastern Pacific, a 12-km nest covering Utah and parts of adjacent states, and 27 vertical levels (Fig. 1). A 4-km nest covering the Olympic region will be added during summer 2001. Major parameterizations include the Dudhia simple-ice scheme, Dudhia radiation parameterization with cloud interaction, Kain–Fritsch cumulus parameterization, and MRF PBL.

Initial and lateral boundary conditions are provided by the NCEP Eta model. Beginning in summer 2001, a terrain-adapted version of the University of Oklahoma ARPS Data Assimilation System (ADAS) will be used to incorporate data from more than 2500 observing sites into the model initial conditions. Such data is provided by MesoWest, a joint project between NOAA–CIRP and the NWS that collects data from 70 mesonets in the western United States (http://www.met.utah.edu/mesowest).

Prior to September 2000, the real-time MM5 was run on an SGI Origin 2000 (16 processors) maintained by the University of Utah Center for High Performance Computing (CHPC). Since then, it has run on a CHPC-maintained Beowulf cluster. Using eight 700 Mhz AMD Athalon processors; a 36-h forecast requires 80 min to complete. An upgrade this summer to sixteen 1.3 GHz AMD Athalon processors will allow for the addition of a 4-km inner nest that will cover the Olympic region and provide model guidance to Olympic forecasters for several months prior to the Olympics.

3. MODEL PRODUCTS AND AVAILABILITY

Hourly model output is converted to netCDF and ingested into NWS AWIPS systems at the NWS Western Region Headquarters and Salt Lake City Forecast Office. The latter is home of the Olympic Weather Operations Center. In addition, forecasters working at the five outdoor Olympic venues (Snowbasin, Deer Valley, Park City, the Utah Winter Sports Park, and Wasatch Mountain State Park) access MM5 output using FX-NET, an AWIPS-based software package developed by the NOAA Forecast Systems Laboratory (FSL). FX-NET allows for the graphical analysis of MM5 output stored at the NWS Western Region Headquarters, including integration with other datasets (e.g., surface observations, satellite and radar imagery, other model output). MM5 products can

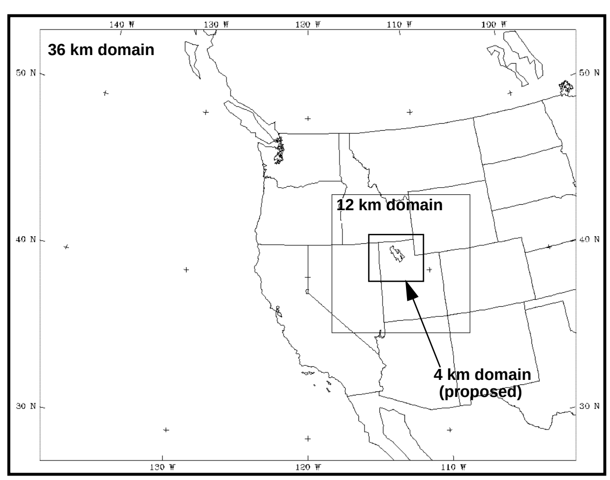

Figure 1. Domains of the NOAA-CIRP real-time MM5.

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also be accessed by the public via the commercial internet (www.met.utah.edu/jimsteen/mm5).

Some products produced by Olympic meteorologists require temperature, wind, and relative humidity forecasts at 1-h intervals. Because model biases and inadequate terrain representation limit the application of raw model output for such forecasts, MM5-based model output statistics (MM5–MOS) was developed and used for weather prediction during Olympic test events held in winter 2000-2001 (e.g, Fig. 2). Two years of observations and MM5 forecasts from the 12-km domain were used to train MOS-equations for Olympic venues and other weather sensitive locations. At Olympic venues with substantial variability in surface weather conditions, MM5–MOS was developed for multiple observing sites.

Using additional forecasts and observations from winter 2000-2001, new MM5–MOS equations are being developed for use during the Olympics. Preliminary evaluation of these equations relative to an independent dataset shows MM5–MOS is considerably more accurate than raw model output and, averaged over several observing sites, exhibits comparable or slightly improved performance relative to NGM MOS at SLC (e.g., Fig. 3).

4. MODEL EVALUATION DURING IPEX

The Intermountain Precipitation Experiment (IPEX) was held near Salt Lake City during February 2000 to improve the understanding and prediction of orographic and lake-effect precipitation. As part of IPEX, precipitation forecasts by the NOAA-CIRP real-time MM5 were evaluated. It was found that the MM5 often outperformed the Eta and Aviation models over regions of high terrain, primarily due to better terrain representation. However, in locations where fine scale terrain features were not resolved by the MM5, such as the narrow, relatively low-elevation Wasatch Mountain Valleys, forecasts performed badly in many cases. An objective technique based upon the students-t test for the difference between two means was used to evaluate the skillfulness of MM5 forecasts in each NWS zone. Table 1 shows that the MM5 provided skillful forecasts in most zones much of the time; however, the Wasatch Mountain Valleys zone had a bias toward too much precipitation due to poor terrain representation.

Time/Date(Local)	Temperature (f)	Dewpoint (f)	Relative Humidity (%)	Wind Speed (mph)	Wind Direction	Raw Model 1–hour Accumulated Precip (in)	Raw–Model Total Accum. Precip (in)
09:00 pm Apr 24 2001	37.8	20.7	55.8	3.5	SE ↖ (114)	0.00	0.00
10:00 pm Apr 24 2001	37.1	20.4	56.3	4.1	SE ↖ (122)	0.00	0.00
11:00 pm Apr 24 2001	36.1	21.0	57.6	3.8	SE ↖ (148)	0.00	0.00
12:00 am Apr 25 2001	35.2	21.6	58.3	3.1	S ↑ (173)	0.00	0.00
01:00 am Apr 25 2001	35.0	20.7	57.3	2.6	S ↑ (177)	0.00	0.00
02:00 am Apr 25 2001	34.9	19.7	55.2	2.5	S ↑ (192)	0.00	0.00
03:00 am Apr 25 2001	34.9	18.7	53.2	2.5	SW ↗ (210)	0.00	0.00
04:00 am Apr 25 2001	34.7	19.4	56.8	4.5	S ↑ (183)	0.00	0.00
05:00 am Apr 25 2001	34.5	20.0	60.1	6.4	S ↑ (172)	0.00	0.00
06:00 am Apr 25 2001	34.3	20.1	62.0	8.3	S ↑ (169)	0.00	0.00
07:00 am Apr 25 2001	34.5	19.6	59.4	8.7	S ↑ (200)	0.00	0.00
08:00 am Apr 25 2001	35.9	19.6	55.6	9.1	SW ↗ (232)	0.00	0.00
09:00 am Apr 25 2001	39.6	19.5	47.3	10.2	W → (262)	0.00	0.00
10:00 am Apr 25 2001	41.7	18.5	42.7	10.0	W → (279)	0.00	0.00
11:00 am Apr 25 2001	42.2	17.9	43.3	9.4	W → (278)	0.00	0.00
12:00 pm Apr 25 2001	42.8	17.6	44.1	8.3	W → (282)	0.00	0.00
01:00 pm Apr 25 2001	44.1	18.5	44.7	7.9	W → (280)	0.00	0.00
02:00 pm Apr 25 2001	44.9	19.4	46.0	7.9	W → (276)	0.00	0.00
03:00 pm Apr 25 2001	45.2	20.4	47.7	8.1	W → (273)	0.00	0.00
04:00 pm Apr 25 2001	45.5	18.4	42.5	8.5	W → (285)	0.00	0.00
05:00 pm Apr 25 2001	45.8	16.2	37.3	8.8	NW ↘ (334)	0.00	0.00
06:00 pm Apr 25 2001	45.7	14.2	32.5	9.6	NE ↙ (067)	0.00	0.00
07:00 pm Apr 25 2001	47.8	14.0	19.5	9.4	E ← (109)	0.00	0.00
08:00 pm Apr 25 2001	48.7	15.3	13.8	8.8	SE ↖ (118)	0.00	0.00
09:00 pm Apr 25 2001	48.9	16.1	8.9	8.0	SE ↖ (127)	0.00	0.00
10:00 pm Apr 25 2001	47.8	17.6	17.4	7.0	SE ↖ (113)	0.00	0.00
11:00 pm Apr 25 2001	47.0	17.6	24.7	6.2	NE ↙ (025)	0.00	0.00
12:00 am Apr 26 2001	46.2	17.5	33.5	5.7	N ↓ (338)	0.00	0.00
01:00 am Apr 26 2001	44.3	18.6	36.7	8.5	NE ↙ (053)	0.00	0.00
02:00 am Apr 26 2001	42.1	18.9	38.5	11.8	E ← (088)	0.00	0.00
03:00 am Apr 26 2001	40.9	18.0	36.4	14.8	W → (286)	0.00	0.00
04:00 am Apr 26 2001	40.8	16.9	35.1	12.6	W → (286)	0.00	0.00
05:00 am Apr 26 2001	40.8	16.2	34.1	10.6	W → (286)	0.00	0.00
06:00 am Apr 26 2001	40.8	16.0	34.4	8.3	W → (284)	0.00	0.00

Figure 2 Sample MM5–MOS forecast for Allen's Peak (top of the Olympic Men's Downhill).

5. ACKNOWLEDGEMENTS

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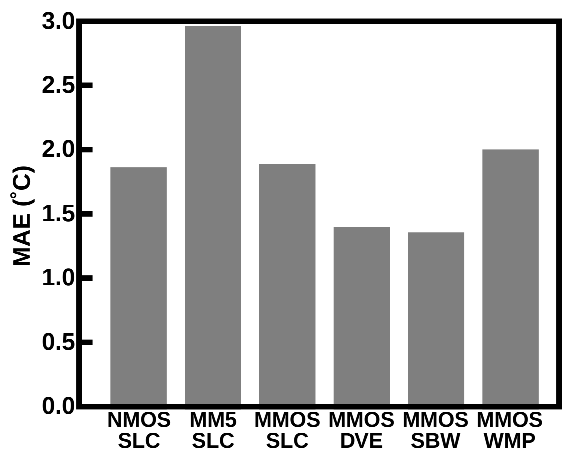

Figure 3. Temperature mean absolute errors (MAE, ˚C) at selected sites. NGM MOS at Salt Lake City (NMOS SLC), MM5 at SLC (MM5 SLC), MM5 MOS at SLC (MMOS SLC), MM5 MOS at Deer Valley (MMOS DVE), MM5 MOS at Snowbasin (MMOS SBW), and MM5 MOS at Wasatch Mtn State Park (MMOS WMP).

Table 1 MM5 precipitation performance over northern Utah NWS forecast zones during IPEX.

Zone	Under Forecast	Skillful	Over Forecast	False Alarms/ No Obs. Precip	Mean Bias (mm)	Mean Observed Precip (mm)
Wasatch Front[a]	4	7	5	2/7	0.2	2.6
Wasatch Mountains[b]	1	9	6	2/7	1.2	5.3
GSL Desert and Mts	6	5	3	3/9	-1.4	3.1
SL and Tooele Valley	4	8	3	2/8	-0.3	2.6
N Wasatch Front	3	6	5	2/9	0.3	3.0
S Wasatch Front	1	10	5	2/7	0.6	2.6
N Wasatch Mts	5	9	2	1/7	-1.2	6.6
S Wasatch Mts	3	8	5	2/7	1.1	6.4
Wasatch Mtn Valleys	0	5	10	2/8	4.8	2.6

a. Includes SL and Tooele Valley, N Wasatch Front, and S Wasatch Front.
b. Includes N Wasatch Mts, S Wasatch Mts, and Wasatch Mtn Valleys.