P5.1 ASSESSING THE VALUE OF INCREASED MODEL RESOLUTION IN FORECASTING FIRE DANGER

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1. INTRODUCTION

The fire season of 2000 was used as a case study to assess the value of increasing mesoscale model resolution for fire weather and fire danger forecasting. With a domain centered on Western Montana and Northern Idaho, MM5 simulations were run at 36, 12, and 4-km resolutions for a 30 day period at the height of the fire season. Verification analyses for meteorological parameters that influence fire danger rating were done for observation sites within the model 4km domain (figure 1).

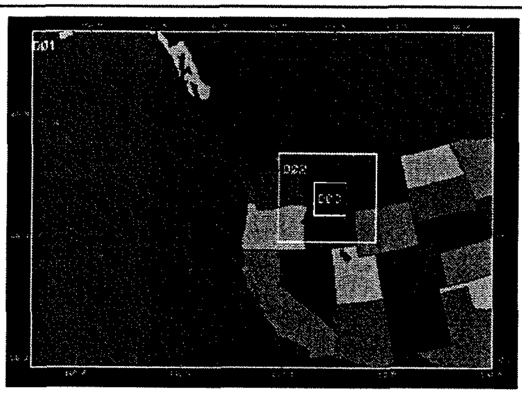

Fig. 1. Domain nests used for MM5 model simulations of the 2000 Fire Season. Study area for verification purposes is a subset of domain 3. The horizontal resolution is 36-km in domain 01, 12-km in domain 02, and 4-km in domain 03.

Analysis of Mean Absolute Error, Root Mean Square Error and Bias for temperature, relative humidity and wind speed and direction show only minor differences between the model resolutions. Results also highlight known MM5 model biases and suggest a need for adjustments to the land surface model during extended dry periods.

In addition, MM5 model output data was used to calculate National Fire Danger Rating System (NFDRS) indexes. The model-predicted indexes at all three resolutions were compared with those computed at Remote Automatic Weather Stations (RAWS), and with the growth of active wildfires. The model biases in the fire weather variables carried through to the NFDRS indexes, so that in general the MM5 under-predicted fire danger. This represents the first step in a process to generate real time NFDRS forecasts using MM5 model output.

2. RESULTS OF METEOROLOGICAL VERIFICATION

The meteorological parameters which are used in NFDRS calculations of fire danger include temperature, relative humidity, and wind speed. We have also looked at wind direction because accurate forecasts of wind direction are also important in fire weather forecasting. Traditional meteorological verification techniques which compare predicted and observed values at point locations were used. A bilinear interpolation scheme was used to extract point values from model grid fields. These values were then used to derive model minus observed statistics for mean

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error, mean absolute error and root mean square error for all available observation sites within the 4km domain.

2.1 *Temperature*

Table 1 shows the results for temperature. Note that the differences between model resolution tend to be small compared with the differences between forecast time intervals. This is a reflection of the diurnal bias of the model. In general the improvement in verification scores between resolutions is not enough to be considered operationally significant. When model performance was evaluated in terms of best and worst performance for each observation site at each forecast time interval, it was found that for temperature the 4-km domain was best most often at 48% of the time but was also worst most often at 42% of the time. The 12-km domain was least likely to be worst at 17%of the time but had the best score only 23% of the time. The 36-km domain on the other hand, was worst 41% of the time and best less than a third of the time at 29%.

2.2 *Relative Humidity*

The results for relative humidity are shown in Table 2. Note that in general the errors are quite large. We believe that this may be partially explained by the fact that the model is initialized with climatological soil moisture values. Because soil moisture values were well below normal during this summer the result was excessively high humidity values. Evaluation of point statistics by station and forecast verification time showed that the 4-km resolution was likely to have the best MAE score 56% of the time while the 36km was most likely to be worst 55% of the time. The 12-km was least likely to be either best or worst.

Table 1. Differences in temperature (^{o}C) of modeled minus observed for Mean Absolute Error (MAE), Root Mean Square Error(RMS) and Mean Error (Bias).

Forecast Hour	Local Time	MAE			RMS			Bias		
		36km	*12km*	*4km*	*36km*	*12km*	*4km*	*36km*	*12km*	*4km*
6hr	2400	3.38	3.33	3.43	4.11	4.03	4.29	0.13	0.20	1.47
12hr	0600	3.99	4.01	4.43	4.76	4.80	5.40	2.05	2.11	3.49
18hr	1200	3.13	3.26	3.31	3.84	4.06	4.21	-0.04	0.31	0.87
24hr	1800	5.14	4.62	4.02	5.71	5.26	4.70	-5.03	-4.44	-3.59
30hr	2400	3.46	3.18	3.13	4.21	3.89	3.69	-1.47	-1.46	0.07
36hr	0600	3.50	3.54	3.86	4.28	4.28	4.61	0.74	0.97	2.31
42hr	1200	3.54	3.47	3.43	4.43	4.35	4.26	-1.73	-1.24	-0.62
48hr	1800	6.66	6.08	5.30	7.22	6.70	5.98	-6.63	-6.04	-5.21

Table 2. Differences in relative humidity (%) of modeled minus observed for Mean Absolute Error (MAE), Root Mean Square Error(RMS) and Mean Error (Bias).

Forecast Hour	Local Time	MAE			RMS			Bias		
		36km	*12km*	*4km*	*36km*	*12km*	*4km*	*36km*	*12km*	*4km*
6hr	2400	20.14	18.23	16.42	23.87	21.54	19.57	9.82	6.17	-2.26
12hr	0600	20.64	20.02	19.93	24.97	23.60	23.78	8.35	1.96	-8.37
18hr	1200	11.61	11.30	10.74	14.91	14.62	13.98	4.84	3.67	2.32
24hr	1800	14.25	13.10	12.23	16.74	15.37	14.21	12.65	11.23	9.81
30hr	2400	25.18	21.60	18.35	29.70	25.68	21.68	19.99	15.55	7.72
36hr	0600	22.58	20.10	18.87	27.92	24.33	22.04	15.62	8.77	-0.81
42hr	1200	14.13	13.25	12.53	18.53	17.11	15.92	9.21	7.28	5.71
48hr	1800	17.01	15.73	14.27	19.95	18.32	16.47	16.06	14.64	12.77

2.3 *Wind Speed*

The results for Wind Speed are shown in Table 3. Once again the diurnal variations are greater than the variations between resolutions. The differences in MAE from one resolution to another are generally less than .25 m/s which cannot be considered operationally significant. Analysis of best and worst performance for individual stations shows that the 4-km resolution is likely to be best 46% of the time and the 36-km resolution is likely to be worst 47% of the time. The 12-km is again least likely to have the worst MAE score.

Table 3. Differences in wind speed (m/s) of modeled minus observed for Mean Absolute Error (MAE), Root Mean Square Error(RMS) and Mean Error (Bias).

Forecast Hour	Local Time	MAE			RMS			Bias		
		36km	*12km*	*4km*	*36km*	*12km*	*4km*	*36km*	*12km*	*4km*
6hr	**2400**	1.34	1.31	1.39	1.68	1.69	1.77	0.33	0.22	0.52
12hr	**0600**	1.38	1.32	1.45	1.65	1.62	1.80	0.86	0.84	1.04
18hr	**1200**	1.36	1.19	1.09	1.75	1.55	1.46	0.40	0.17	0.27
24hr	**1800**	1.82	1.68	1.75	2.37	2.24	2.26	0.04	0.11	-0.07
30hr	**2400**	1.27	1.27	1.27	1.62	1.65	1.65	0.40	0.34	0.49
36hr	**0600**	1.31	1.30	1.36	1.60	1.61	1.72	0.76	0.74	0.85
42hr	**1200**	1.37	1.28	1.26	1.77	1.65	1.66	0.38	0.30	0.16
48hr	**1800**	1.83	1.72	1.77	2.35	2.22	2.29	0.09	0.13	0.07

2.4 *Wind Direction*

Results for wind direction are shown in Table 4. In this case the 4-km resolution does appear to have a clear advantage, especially at 12 and 36 hours into the forecast run. Station by station analysis of best and worst performance reinforces this conclusion with the 4-km having the best performance 53 percent of the time and the 36 km performing worst 55 percent of the time. As with other parameters, the 12 km is least likely to perform worst.

Table 4. Differences in wind direction (degrees) between modeled minus observed for Mean Absolute Error (MAE), Root Mean Square Error(RMS) and Mean Error (Bias)

Forecast Hour	Local Time	MAE			RMS			Bias		
		36km	*12km*	*4km*	*36km*	*12km*	*4km*	*36km*	*12km*	*4km*
6hr	**2400**	79	77	70	93	91	86	-12	-8	-7
12hr	**0600**	77	73	53	91	89	69	28	12	0
18hr	**1200**	88	82	75	100	95	90	54	59	28
24hr	**1800**	70	67	63	86	83	81	44	41	30
30hr	**2400**	76	75	72	91	88	87	17	15	-1
36hr	**0600**	78	73	58	94	90	75	32	14	1
42hr	**1200**	86	82	71	98	95	86	66	73	40
48hr	**1800**	68	65	66	84	80	82	47	46	35

3. AUTOMATION AND VERIFICATION OF NFDRS FORECASTS

Calculation of National Fire Danger Rating System Indices has historically been done using point observations averaged over a fire weather zone. Forecasts of trends or actual values for temperature, relative humidity, wind speed and 10-hr fuel moisture are then applied to arrive at Fire Danger forecasts for the following day. By using MM5 model output for the forecast weather parameters input into NFDRS equations, we have been able to produce forecasted NFDRS values in gridded format over the full model domain. Direct output fields from MM5 include temperature, relative humidity, wind speed and precipitation. In addition, several fields must be derived from the MM5 output. These include precipitation duration, cloud cover, maximum and minimum temperature, and maximum and minimum precipitation. The NFDRS calculations also require a weekly updated Relative Greenness field derived from satellite observations.

3.1 *Evaluation of forecast NFDRS Indices*

In order to evaluate the value of NFDRS forecasts at differing model resolutions the data are being looked at in a number of ways. First, the indices have been mapped using ARCGIS and compared with data from RAWS stations mapped by zonal average and interpolated using a distance weighted scheme. This allowed a quick visual inspection of the NFDRS forecast for each day to evaluate the general performance of the model across the landscape. The resulting images can be viewed at http://www.fs.fed.us/pnw/fera//mm5case/.

Next, the fire weather zone and interpolated index values calculated from RAWS observations and the model forecast index values will be determined within known fire perimeters from several large fires which occurred during the 2000 fire season. Figure 2 shows values for ERC for a period in August 2000. These values will be compared using objective forecast verification statistical techniques. They will also be compared with actual acreage gains from the selected fires. While it is understood that Fire Danger Rating should not be confused with Fire Behavior Analysis it is also felt that the best way to evaluate a Fire Danger Index is to test it against actual fire occurrence.

Finally, the forecast index values of Energy Release Component and Burning Index were compared with threshold values reflecting 90^{th} and 97^{th} percentile for these indexes. Because these thresholds are used operationally to manage resources and are presented to firefighters through pocket cards, it seems important that whether or not we are able to model hard number of fire danger indices with extreme accuracy, we must certainly be able to forecast the threshold values of significance to fire managers if the model is to be useful.

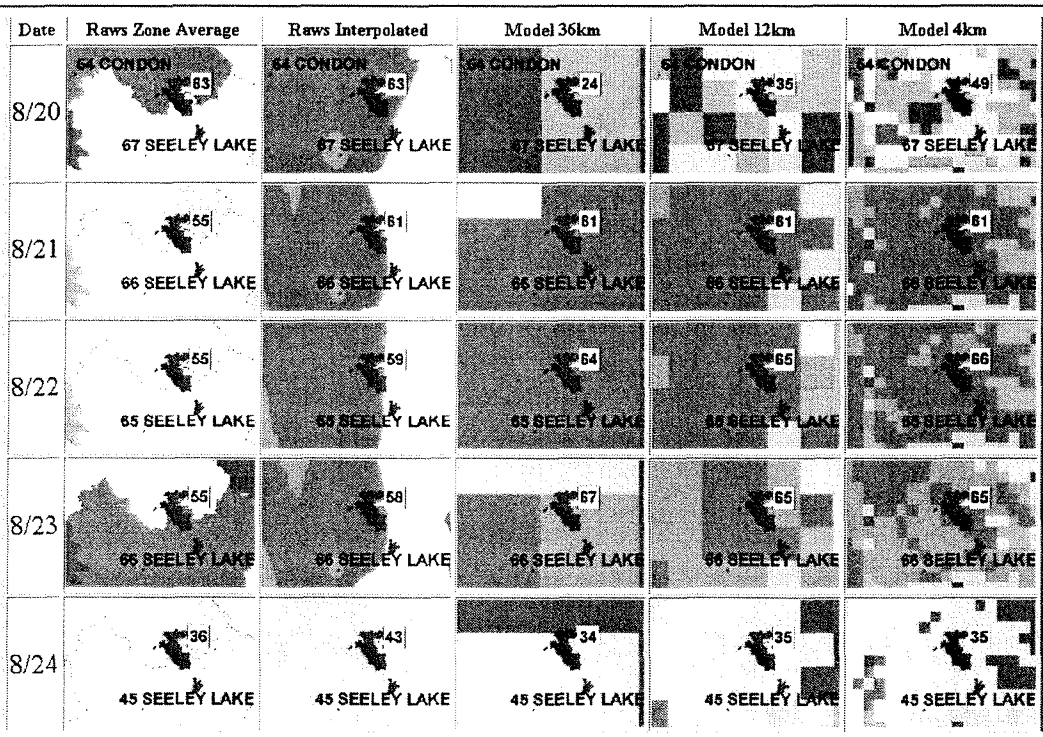

Fig. 2. Comparison of observed ERC with Model forecast ERC for the Monture Spread Ridge Complex, August 2000. The color scale ranges from green for low values through yellow to orange and red for high values. The Fire perimeter is shown in red.

4. CONCLUSIONS

This work represents the first step toward automation of NFDRS forecasting. We have shown that coupling of MM5 with NFDRS is possible and have evaluated the results using data from a significant fire season. Ultimately, this type of modeling will allow forecasts of NFDRS indices to be made available on a longer and more continuous temporal scale as well as at a finer spatial resolution than has been possible in the past.

We have not found significant differences in forecast weather parameters between model resolution at 36-km, 12-km, and 4-km. Analysis of differences in NFDRS forecasts is ongoing and may finally depend more on the needs of fire managers for finer resolution information than on differences in model performance at finer resolution.

For further information about this work please refer to our website at http://www.fs.fed.us/pnw/fera//mm5case/

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