

Impact of land surface simulation on modeled meteorological fields during a pollution episode in the Lower Fraser Valley

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1. Introduction

The Lower Fraser Valley (LFV) of British Columbia, which is located near the Canada/US border at 49° N, features extreme topographic variations and complex terrain (Figure 1). It is a river delta with a wide western end and is gradually narrowed to the east. The Coast Mountain Ranges and the Cascade Ranges sit in the north and southeast, respectively. This valley reaches the shoreline of the Strait of Georgia with Vancouver Island located to the west. Metropolitan Vancouver is on the valley floor.

The high pressure system in the summer often leads to subsidence and stagnant weather in this area (McKendry, 1994). In this circumstance, the

thermally and topographically generated winds become dominant (Steyn and Oke, 1982). The urban emissions are usually trapped there, and cause high ozone levels and impaired visibility.

The pollutants mainly move, diffuse and undergo chemical transformations in the lower part of the atmosphere, which is affected by the land surface. The coastal complex terrain in the LFV and weak synoptic system during air pollution episodes probably cause more land surface influence on the lower atmosphere. The objective of this work is to investigate the effects of the land surface resolution and the modeling of the land surface water and energy fluxes on the modeled atmosphere in this region during the Pacific '93 pollution episode (Steyn et al. 1997).

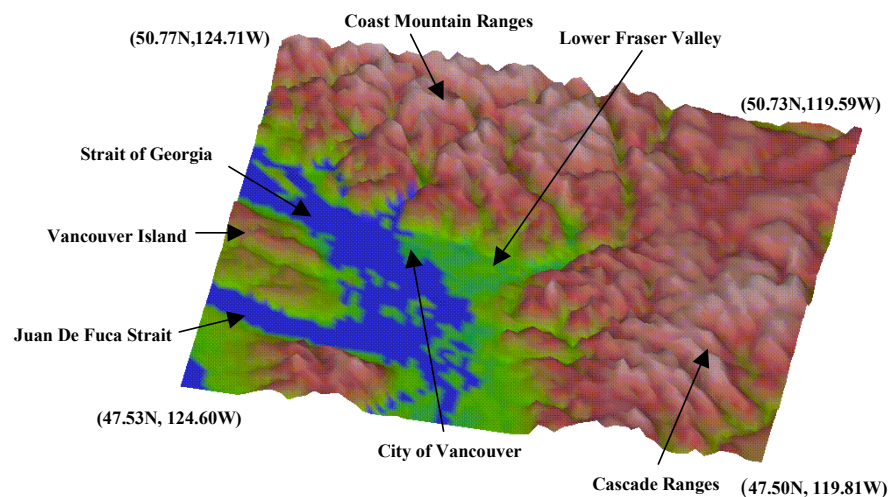


Figure 1. Topography of the LFV and its vicinity

2. Methodology

Three scenarios were run for the episode of July 30 to Aug. 9, 1993. They had the same multiple nesting configuration, FDDA configuration and other physical options in MM5 (Grell et al. 1994). Scenario one (referred to as S1) used ten-minute (about 18.5km) resolution PSU/NCAR terrain height and land-use data set for all three nested domains. The Blackadar force/restore scheme with five-layer soil model was applied. Scenario two (S2) was the same as S1 except that the ten-minute PSU/NCAR terrain height and land-use data set was used for the outermost domain, the five-minute (about 9.25km) PSU/NCAR terrain height and five-minute USGS vegetation data set for the intermediate domain, and the 30-second (about 0.925km) USGS terrain height and vegetation data set for the innermost domain. Scenario three (S3) used the same data sets as that of S2 to designate the terrain height and land-use at the model grids, but the OSU/NCEP Eta LSM (Chen et al. 1996) was applied instead of the Blackadar force/restore scheme with five-layer soil model.

The modeled results were evaluated against Pacific '93 field study data using both a statistical technique and a pattern comparison method. The statistics included the observed and modeled means, standard deviations, root-mean-squared errors between modeled and observed (RMSE) along with the systematic and unsystematic components of RSME (RMSE_s and RMSE_u, respectively) and the index of agreement (Steyn and Mckendry, 1988). This technique was applied to the surface wind and temperature. The pattern comparison method was applied to the near ground wind field pattern and vertical wind and temperature profiles.

3. Results

Surface measurements at 27 sites were used in the statistical analysis. The modeled wind and temperature were interpolated to 10m and 2m at these sites.

Figure 2 shows the average temperature at these 27 sites from 01:00 PST Aug.1 to 00:00 PST Aug. 7, 1993. S1 modeled diurnal temperature swings had larger biases than those of the observed, while those of S2 and S3 were closer to the observations. The differences between S2 and S3 were less obvious.

The standard deviations of S1, S2 and S3 modeled temperatures did not present much difference with each other. They were all close to the standard deviations of the observed. Thus, the modeled distributions of S1, S2 and S3 should be in good agreement to those of the observations.

The magnitudes of RMSEs between modeled and observed surface temperature of the three scenarios showed obvious differences. RMSEs of S2 and S3 were smaller than those of S1. According to Willmott (1985), RMSE_u is a measure of precision. Smaller RMSE_u implies better surface temperature modeling performance. Again, we did not see significant differences between S2 and S3.

The modeled and observed means of the wind directions showed diurnal cycles from Aug. 1 to Aug. 5, whereas there was no clear cycle on Aug. 6. These cycles confirmed the existence of the land-sea breeze and up-down slope winds in the region. Although biases between the modeled and the observed means existed, S2 and S3 results were closer to the observed. S3 presented a little better modeled surface wind direction than S2.

The standard deviations of S2 and S3 are closer to those of the observed. RMSEs of the wind speeds decreased from S1 through S2 to S3.

The average indices of agreement for surface temperatures of S1, S2, and S3 were 0.542, 0.588, and 0.601, respectively. The average indices of agreement for surface wind speeds of S1, S2, and S3 were 0.658, 0.715 and 0.718.

The near ground surface wind fields were extremely complicated due to the complex terrain in the region. The Strait of Georgia was an especially challenging area in previous modeling exercises.

Snapshots of the wind fields on Aug. 5, 1993 are shown in Figure 3. According to the pattern comparison results, S3 gave the best results among the three model runs. Despite some better modeled winds at one or two sites with S1 or S2, the overall patterns of S3 were encouragingly good in the area near the Strait of Georgia.

In terms of vertical wind and temperature profiles, S1, S2 and S3 showed differences

below the 4000m AGL. The modeled profiles were compared with the observations at three sites. Langley is located at the middle of the LFV floor. Harris Road site is close to the entrance of one of the LFV tributary valleys. Therefore, the wind profiles at Harris Road are significantly affected by up and down slope flows. The third site is Pitt Lake, which is within a tributary valley of the LFV. The measurements were conducted at an island in Pitt Lake. The terrain is extremely complex around this site.

Temperature profiles were better simulated than the wind profiles. There were discrepancies with respect to the detailed variations of the profiles. At Langley, we did not see obvious improvement with high resolution and OSU/NCEP Eta LSM. However, we saw the positive effects at Harris Road and Pitt Lake. S3 modeled temperature profiles were better than those of S2 at Harris Road and Pitt Lake. S1, S2 and S3 modeled temperature profiles had relatively larger biases to the observed in the morning than in the afternoon while this phenomenon was not found at Langley.

The modeled wind directions at Langley were in fairly good agreement with the observed. The differences among S1, S2 and S3 modeled wind directions were less evident. The modeled wind directions at Harris Road and Pitt Lake were more westerly than the observed. S3 modeled winds directions were better than those of S2, while S2 performed better than S1.

S3 showed more positive impact on the modeled wind speeds at Pitt Lake than at Harris Road. At Harris Road, all of the modeled wind speeds were smaller than the observed although S3 modeled speeds were closest to the observed. At Langley, S1 and S2 modeled wind speeds were similar. S3 modeled results were better than those of S1 and S2.

4. Conclusion

Based on the statistics, MM5 with high resolution land surface and MM5 with high resolution land surface combined with more sophisticated LSM (OSU/NCEP Eta LSM) showed similar model performance with respect to the surface wind and temperature during the episode. Their performance was better than MM5 using low resolution land surface data sets.

The high resolution land surface combined with OSU/NCEP Eta LSM in the modeling gave superior near ground wind field patterns.

High resolution land surface and the more sophisticated LSM showed more positive impacts on the modeled wind and temperature profiles near the mountains (Harris Road and Pitt Lake) than at the center of the valley (Langley).

5. References

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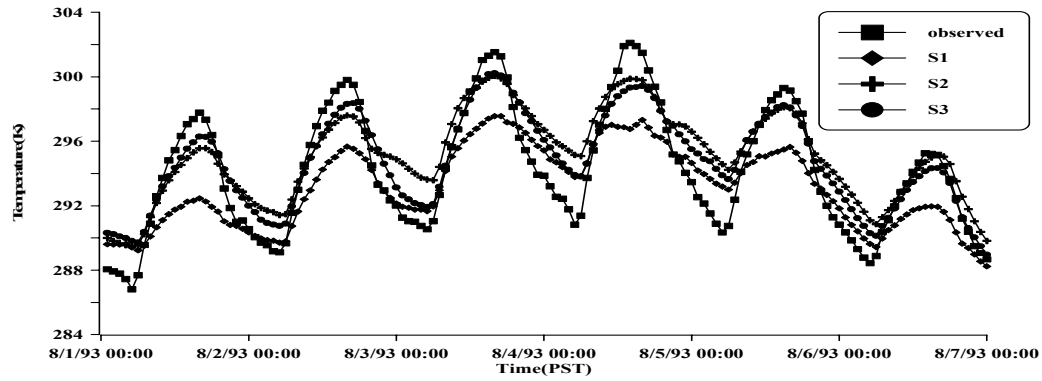


Figure 2. The evolution of the temperature means during 1-6 of August, 1993.

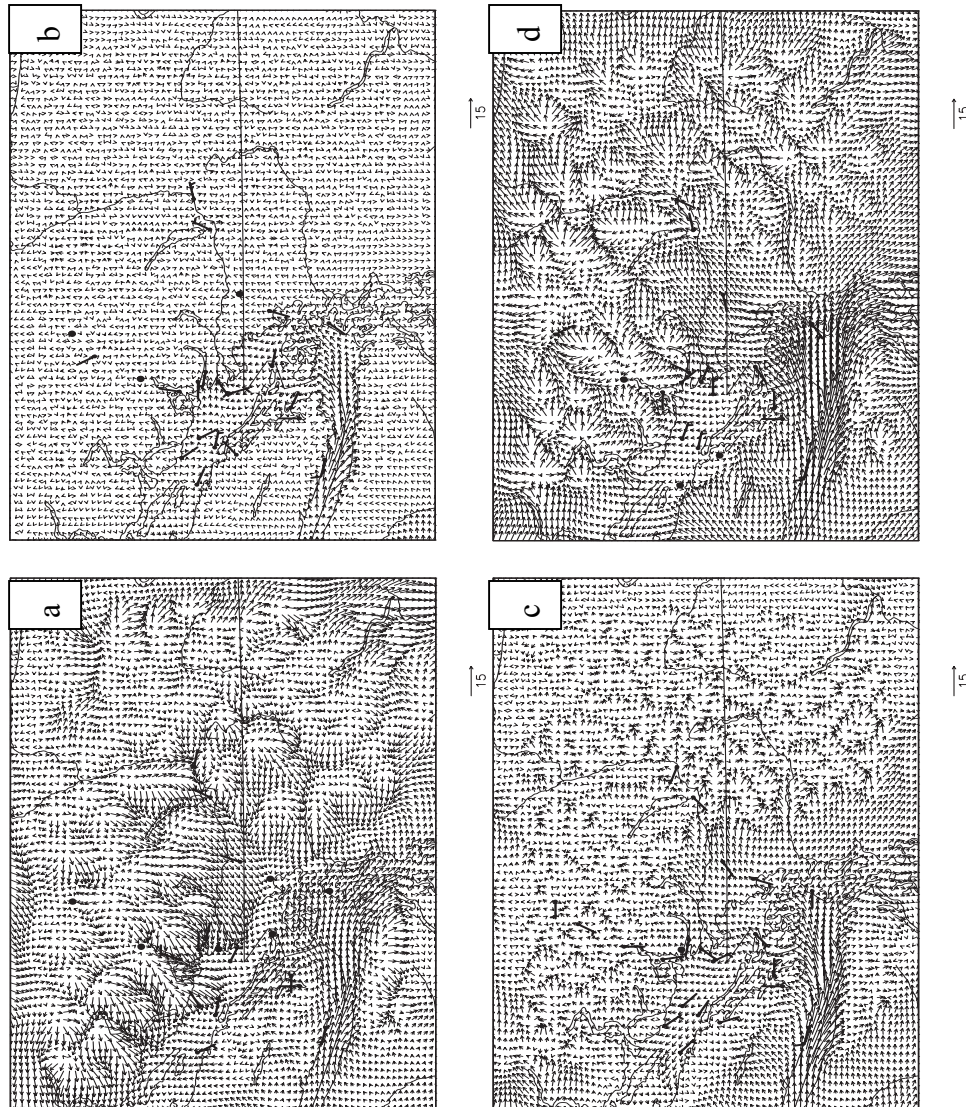


Figure 3. S3 modeled wind fields on the first half sigma level and the interpolated observed winds on this level. Wind vectors show the modeled winds, and barbs show the observations. The arrow length scaling is below each image. For the wind barbs, a short bar is for 5m/s, a long bar for 10m/s, a line with no barb for less than 3m/s, and a circle for zero. The wind fields shown were at (a) 00:00 PST, (b) 10:00 PST, (c) 16:00 PST, (d) 20:00 PST August 5, 1993.