WINTERTIME STAGNATION EPISODES NEAR POCATELLO IDAHO

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1. INTRODUCTION

The use of MM5 3-dimensional data to drive dispersion models has become increasingly popular in the last few years. In areas of complex terrain and/or sparse data, MM5 winds are often the only reasonable meteorological data source. Dispersion models such as CALPUFF are often used to predict concentrations of trace gasses and fine particles (PM_{10}) in regions up to a few hundred km from modeled sources.

This work was performed under contract from EQM Inc, in turn under contract with the Idaho Department of Environmental Quality (IDEQ), and the US EPA. The dispersion modeling, using MM5 3-D data, is part of the Portneuf Valley Non-Attainment Area State Implementation Plan.

Simulations for three episodes of particularly poor air quality have been performed: 2-3 January 1995, 5-7 February 1995, and 23-31 December 1999. These periods featured classic wintertime stagnation, with a low capping inversion, strongly stable temperature gradients near the surface, night-time fog formation, and down-slope drainage flows in both the Snake River and Portneuf Valleys. High levels of PM_{10}, SO_2, and sufates were all measured at several sites in and near Pocatello, ID on these days.

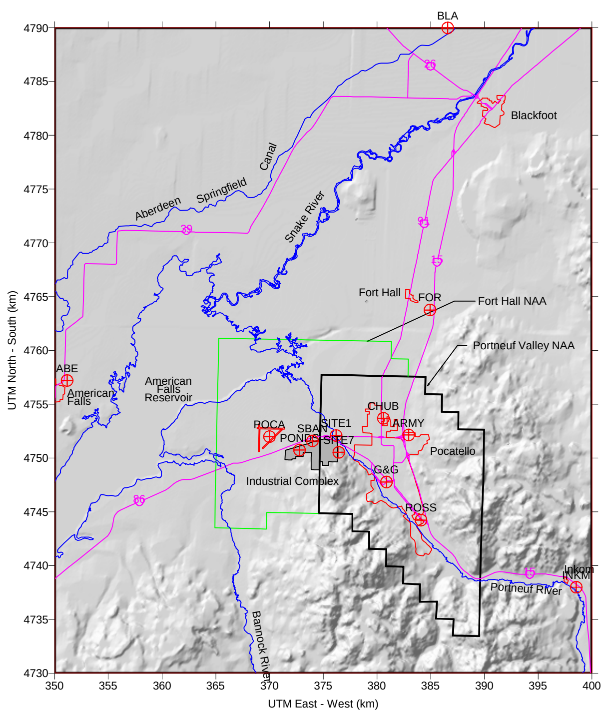

Figure 1: Inner-most domain, with MET stations

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2. IN-SITU DATA

During the 1995 episodes, an observational study was underway gathering both meteorological and chemical data. A series of MET stations were operating, as well as a SODAR at the Garrett & Gould site (G&G, Figure 1). Several MET sites were operated by the various corporations at the industrial complex, and the Shoshone-Bannock tribe also operated a site on the fenceline of the industrial park. Additionally, MET data from the Idaho Mesonet for two (three) stations in the Snake River Valley were available in 1995 (1999), as well as METAR data from Pocatello airport.

3. MM5 INPUT DATA AND OPTIONS

MM5v3.5 was run twice for each simulation; one run with 36 and 12 km two-way nested domains, and a second run (after a NESTDOWN) with 3 and 1 km two-way nested domains. The 36 km domain was 80×101 gridpoints, and the rest were 70×70 gridpoints. All domains used 31 vertical half-levels, with more extra levels near the surface. The new Kain-Fritch cumulus scheme (KF2) was used at 36 and 12 km, with the Reisner II explicit moisture scheme at all grid spacings. The Rapid Radiative Transfer Model was used, along with the multi-layer soil model. Various PBL schemes were tried, due to the critical nature of the problem -- advecting ground-based or slightly elevated chemical tracer sources. The outer two grids were nudged, with double the default nudging coefficients. Input data included ds090.0 (“NNRP”), ds083/2.1 (“FNL”) and ds353.4/ds464.0 (NCEP ADP Obs data). Thanks to Rotang, MM5 was run on a small cluster of dual-Athlon linux machines.

4. MODEL-DATA COMPARISONS

The MM5 wind field over the 1-km modeling domain is quite complex, with gap flows and orographically-induced eddies. The upper level winds at 4000m (not shown) are from the generally west, and show no sign of the effects of the terrain, as expected. MM5 correctly models the large-scale drainage flow down the Snake River Valley, but does not do as well with the smaller-scale drainage flow down the Portneuf Valley.

With only 14 total days of simulation and less than one dozen in-situ observation stations available for any one simulation, a statistical evaluation of the 1-km MM5 data is probably not warranted. Instead, time series, individual soundings, and individual wind fields are presented.

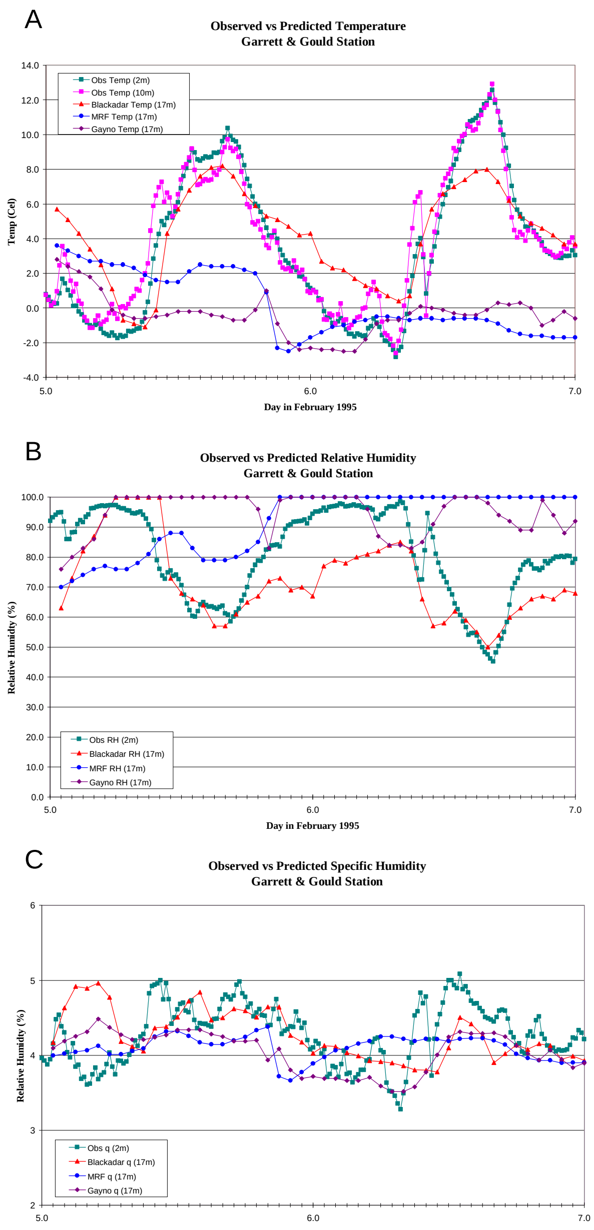

Figure 2: (A)Temperature, (B) relative humidity, and (C) mixing ratio observed at Garrett & Gould, and from the MM5 model.

4.1 Garrett & Gould site

For brevity, only time-series for the February episode are shown, in Figure 2. The Blackadar PBL scheme does reasonably well capturing the diurnal cycle of temperature, but the MRF and Gayno-Seaman (GS) schemes fail. It appears from Figure 3 that the abundance of fog near the surface may be keeping the temperature from rising during the days. Note, however, that the MRF scheme did not produce fog until very late on the 5th, yet did not rise appreciably during that day.

The time-series for the December episode (not shown) give a different result: the MRF performed clearly better than the other two PBL schemes. There was again an overabundance of fog, causing generally lower temperatures than observed.

4.2 SODAR data

Sounding from a SODAR that was deployed at the Garrett & Gould site, along with the nearest gridpoint of the MM5 simulations, are shown in Figure 3. The SODAR measures only the lapse rate of temperature (dT/dz), so the potential temperatures were calculated by extrapolating the lapse rate near the surface as measured by the MET station. Thus the SODAR profiles of potential temper-

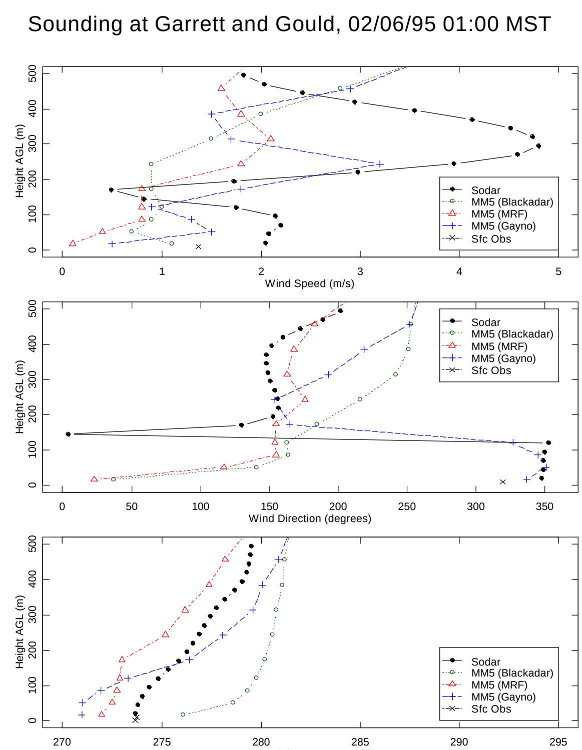

Figure 3: Soundings from the SODAR at Garrett & Gould, and from MM5 using various PBL schemes.

ature may be wrong in absolute value, but should be correct relative to other points in the same profile. Only the GS scheme captured the turning of the ~100 m deep quasi-mixed layer near the surface at 1:00 MST on 2/5/1995. This lowest layer is caused by larger-scale flow down the Snake River Valley slipping under the flow down the Porteneauf Valley to the Southeast of the site.

The MRF scheme showed the opposite behavior for the 1:00 MST sounding on 1/2/1995 (not shown). During this hour, the flow in the lowest 500 m was all from 150º (Southeast), indicating flow down the Portneuf Valley. The Blackadar scheme had ~100-m deep flow up the Portneuf Valley (similar to 1:00 MST on 2/5/1995) while the MRF scheme had light winds that veered a full 510º in the lowest 500 m.

4.3 Wind Fields

1-km wind fields for the Feb 1995 simulations using the MRF and GS scheme are shown in Figures 4 and 5, respectively. Neither scheme catches the down-slope flow from the Portneuf Valley and the mountains in the lower right corner of the domain, evidenced by the wind direction at G&G and Fort Hall (FOR). There is also quite a bit of difference between the overall fields. The MRF scheme produces much stronger flow down the Snake River Valley, yet has nearly stagnant conditions near the city of Pocatello. Wind fields produced by the Blackadar scheme show similar variability.

5. CONCLUSIONS

The difficulty in modeling wintertime stagnation episodes is evident in this study. In fairness, the MM5 model is perhaps primarily used as a tool to study storm systems -- the “large events”, rather than the less exciting, yet important, scenario presented herein. However, the use of MM5 wind fields is increasingly popular among Air Quality professionals and is often a better-quality wind field than other potential choices.

Dispersion modeling with the wind fields produced by the various PBL parameterizations gives significantly different results. Given only three sites with chemical concentration measurements, it is rather difficult to pick the best simulation. The MM5 model remains an important and valuable source of fine-scale 3-D wind fields for use with dispersion models, but much work remains to be done in improving the boundary layer schemes. Correctly modeling parameters like the depth of the boundary layer, the relative humidity, the temperature, and winds are critical to the success of dispersion models.

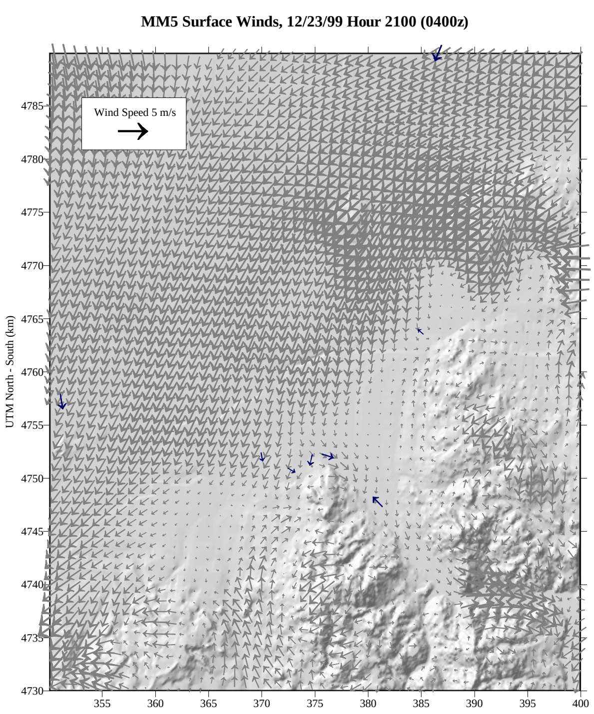

Figure 4: MM5 (MRF scheme) sigma = 0.995 wind field for 21:00 MST 12/23/1999, with observations

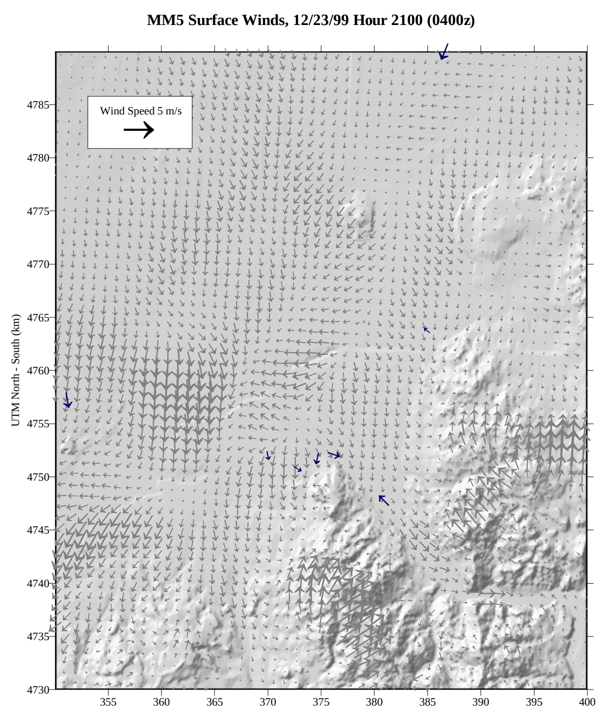

Figure 5: MM5 (Gayno-Seaman scheme) sigma = 0.995 wind field for 21:00 MST 12/23/1999, with observations