INCORPORATING SATELLITE MICROWAVE SOUNDER MEASUREMENTS IN THE MESO-SCALE MODEL MM5

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1. INTRODUCTION

A regional weather forecast system is established based on the UNIX workstation version of the Penn State/National Center for Atmospheric Research MM5 numerical model (Guo and Chen, 1994; Manning and Haagenson, 1992; Haagenson et al., 1994; Grell et al., 1994). The MM5 is a grid-point numerical model designed for mesoscale weather forecasting and research. The vertical coordinate used in the model is sigma coordinate. Use of the sigma coordinate gives an advantage for running the model over complex terrains and across land-ocean boundaries. The model can be run in either hydrostatic or non-hydrostatic modes and contains physical parameterization for clouds, radiation, convection, surface boundary layer processes, etc. Typically, initial conditions and boundary conditions are obtained from a global atmospheric model. Other types of observations (e.g., satellite soundings, radiosondes, and surface measurements) are incorporated in the initial conditions as well as the forecast itself via four-dimensional assimilation techniques.

Conventional radiosonde measurement has been widely used in regional numerical forecasting. However, over the vast ocean area where conventional radiosonde measurement is not available, and over many remote regions, input data sets to a regional model are substantially limited. In order to improve model initialization fields, we incorporate satellite soundings of temperature and relative humidity profiles in regional forecasting using the meso-scale model, MM5. The satellite data and the MM5 model are processed with the SeaSpace Corporation TeraScan package.

2. SATELLITE SOUNDER DATA

The satellite data sets used in the study are the sounder measurements from the Defense Meteorological Satellite Program (DMSP) sensors SSM/T1 and SSM/T2. The SSM/T1 is a microwave radiometer with seven channels. The spot size for these channels is approximately 175 km at nadir. Using the Air Force Global Weather Center (AFGWC) operational D-matrix algorithm, the measurements of SSM/T1 channels can be converted to temperature data at 15 standard pressure levels (1000 mb through 10 mb). The SSM/T2 sensor has five microwave channels. The spot size is approximately 45 km at nadir. The channel measurements can be converted to specific humidity, relative humidity, or dew-point temperature at 6 standard pressure levels (1000 mb through 300 mb).

The derived temperature and water vapor profiles have been compared with radiosonde measurements. In the comparison study, the radiosonde measurements consist of temperature and dew-point temperature at 00 and 12 UTC over the continental United States. The time period is January 1994. Figures 1 and 2 show the comparison results for temperature and specific humidity, respectively. The comparison is based on the subset of satellite profiles whose center latitude and longitude was nearest the available radiosonde stations and that occurred within 1 hour of the 00 and 12 UTC radiosonde observing times. The values shown in the figures are calculated assuming that the radiosonde measurements represent the true values. A positive value of the mean difference indicates that the mean estimate from the DMSP retrieval is higher than the radiosonde measurement.

Figure 1 shows that, compared to the radiosonde data, the DMSP retrievals generally underestimate the temperature values in the lower-middle troposphere. For the levels around the tropopause, the DMSP retrievals have a tendency of overestimating the temperature values. Above 100 mb, the biases are small and the mean differences are within 0.3°C. For the RMS deviation plot, the largest value (6.8°C) is found at the lowest level. The RMS deviation decreases steadily through the middle and upper troposphere. The increasing values around the tropopause correspond to the levels at which the correlations between the DMSP and the radiosonde measurements are low. During the early development of the D-matrix algorithm, Rigone and Stogryn (1977) showed the RMS deviation profiles of temperature for the northern hemisphere spring for tropic, mid-latitude, and Arctic regions, and the profiles for the southern hemisphere fall for the tropic, mid-latitude, and Antarctic regions. The vertical variation of the temperature RMS deviation obtained in our analysis is similar to the profile for the mid-latitude northern hemisphere spring profile presented in Rigone and Stogryn (1977). However, the RMS

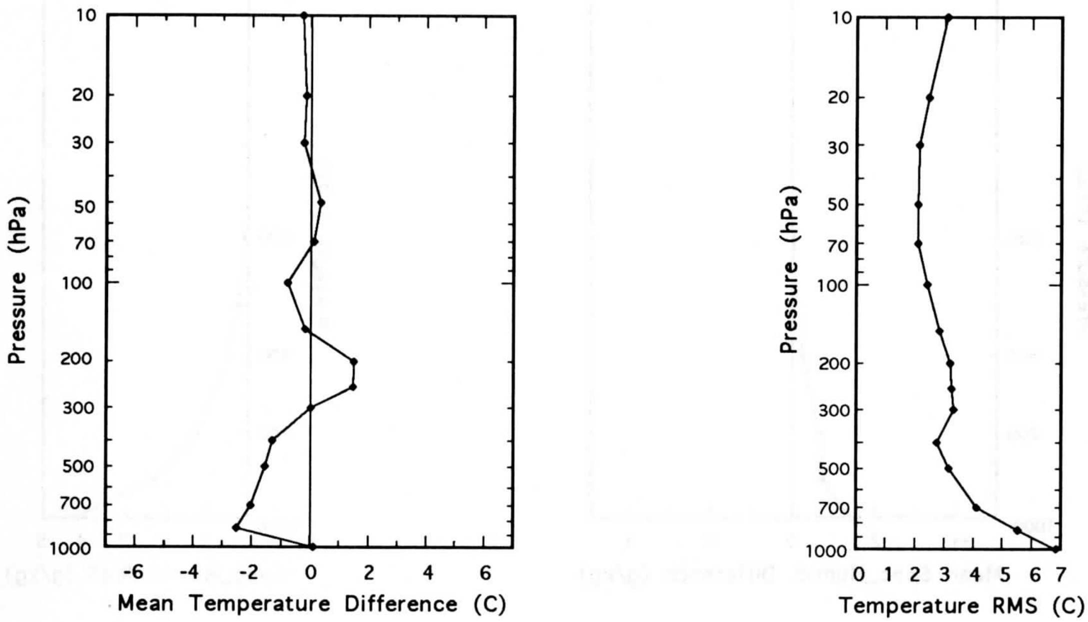

Figure 1. Vertical profiles of the mean difference and the RMS deviation of DMSP SSM/T1 temperature retrievals at pressure levels from 1000 to 10 mb.

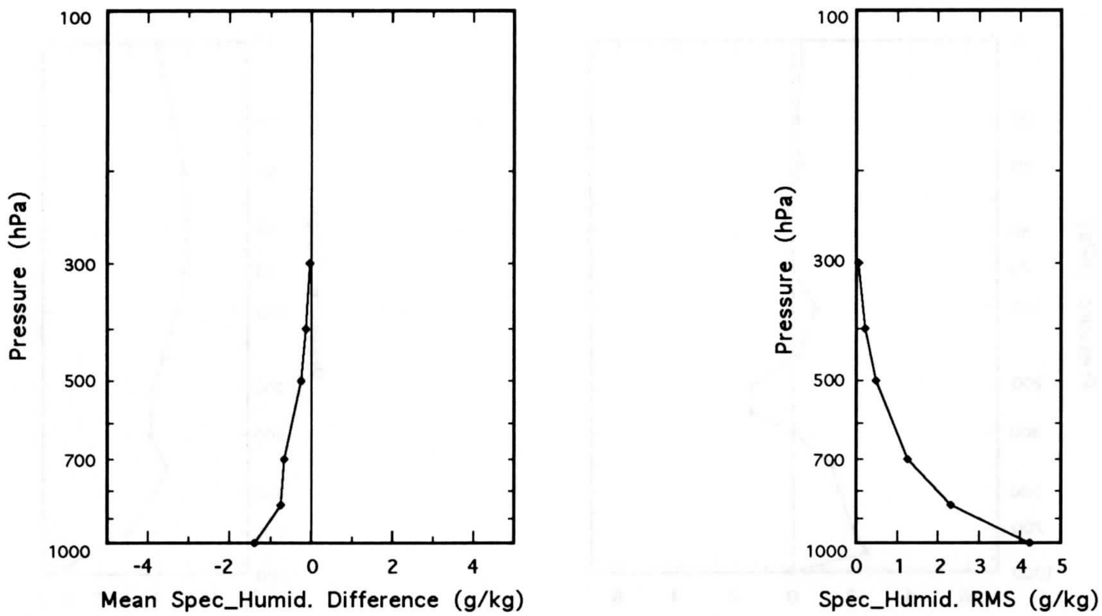

Figure 2. Vertical profiles of the mean difference and the RMS deviation of DMSP SSM/T2 specific humidity retrievals at pressure levels from 1000 to 300 mb.

deviation values shown in Figure 1 are generally 0.5°C larger than the values in that mid-latitude Spring profile.

Figure 2 shows the mean difference and RMS deviation of specific humidity based on the dew-point temperature data from the two sources. Negative values of the mean difference are found at all the pressure levels. This indicates that the DMSP retrievals tend to underestimate the specific humidity. The mean difference is 1.38 g/kg at the lowest level (1000 mb), and decreases to 0.25 g/kg at the middle of the atmosphere (500 mb) and to 0.04 g/kg at the highest level (300 mb). The RMS deviation of specific humidity at 1000 mb is 4.7 g/kg. The value decreases to 2.3 g/kg and 1.2 g/kg at 850 mb and 700 mb, respectively. The RMS deviation values are less than 0.5 g/kg at the upper levels.

3. A GRAPHICAL USER INTERFACE

A graphical user interface (gui) is being developed to process satellite and model data. The object processing is accomplished by using the point-and-click actions of the computer mouse.

The MM5 model is supported by several programs, which are referred to collectively as the MM5 modeling system. The MM5 gui includes all the supporting programs in one panel. The following lists these supporting programs:

- Terrain - Defines model domain and map projection.
- Datagrid - Produces first guess fields from global model data.
- Rswins - Performs objective analysis to blend first-guess fields with in-situ data.
- Forward Interpolation - Interpolates the first guess pressure level data to sigma level data and produces boundary condition data.
- DMSP Soundings - Incorporates satellite microwave soundings for MM5 model assimilation.
- MM5 Model - Performs time integration to produce forecast.
- Backward Interpolation - Interpolates the model forecast data from sigma level to pressure level.

Each of these programs has a dialog box for the user to select parameters associated with the specific programs.

Figure 3 shows an example of the MM5 gui. To work on a particular program, a user may click on the row of tabs at the top of the gui containing the name of this program. The program will then be brought to the forefront of the gui panel. There are several types of controls on this dialog box that allow a user to enter input parameters. A file drawer provides a menu of options to choose from; the currently selected option appears on the front of the file drawer. Text and numeric fields are entered in the fill-in fields. Increment arrows on integer fields can be used to cycle through the range of values available for the field.

4. CASE STUDY

Besides the microwave sounders SSM/T1 and SSM/T2, the microwave sensors on board DMSP also include the Special Sensor Microwave Imager (SSM/I). Based on the AFGWC operational algorithm, surface wind speed can be derived from SSM/I measurement over the ocean area. In this case study, only the SSM/T1 and SSM/T2 data sets are used in the MM5 model initialization. The SSM/I data are set aside as an independent data set for examining the effect of incorporating SSM/T1 and SSM/T2 derived data sets on model input fields.

Figure 4 shows an example of MM5 initial fields of surface wind speed computed with and without incorporating DMSP sounder data, respectively, and comparison of the wind fields to SSM/I derived surface wind. Figure 4a depicts the surface wind speed derived based on the SSM/I measurements from a pass at approximately 12 UT, January 30, 1994. Figures 4b and 4c demonstrate the MM5 initial fields computed by MM5 system. The wind field in Figure 4c is computed using only the NCEP large-scale analysis data. In Figure 4b, the vertical profiles of temperature and relative humidity derived from SSM/T1 and SSM/T2 sounders are incorporated along with the NCEP analysis.

Comparing Figures 4b and 4c to Figure 4a, it is found that Figure 4b more closely represents the variation pattern of the surface wind speed as observed by the SSM/I instrument. The SSM/I measurement shows a narrow belt of wind speed greater than 8 m/s. The boundaries of this wind belt are well reflected in Figure 4b, while in Figure 4c the strong wind belt is much wider than that observed by the SSM/I instrument. For this particular case, neither Figure 4b nor Figure 4c reveal the twin-maximum-center structure shown in Figure 4a. This is partly due to the resolution of SSM/T1 measurement (175 km) which is insufficient to catch the small-scale structure, and partly due to that the

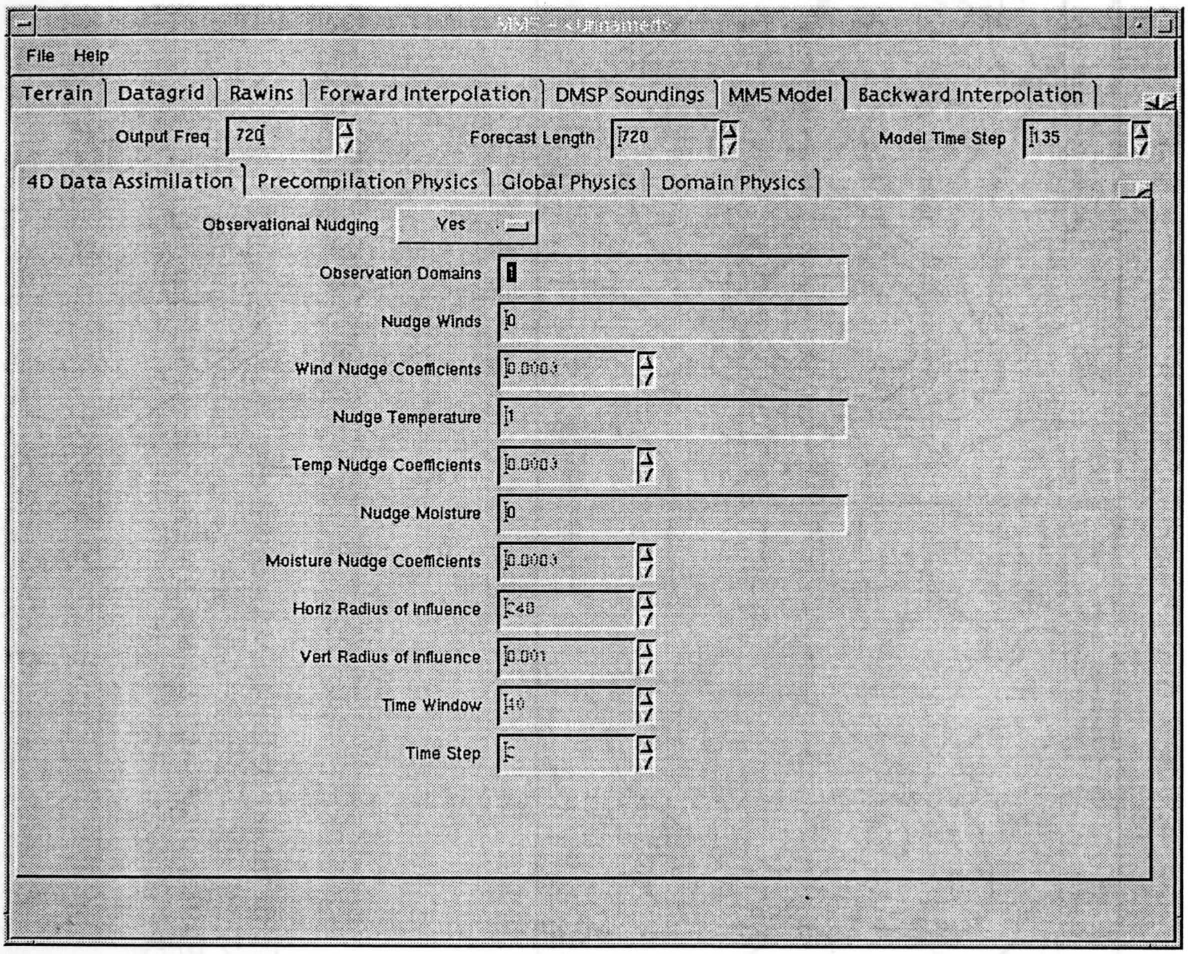

Figure 3. A graphical user interface for the MM5 model.

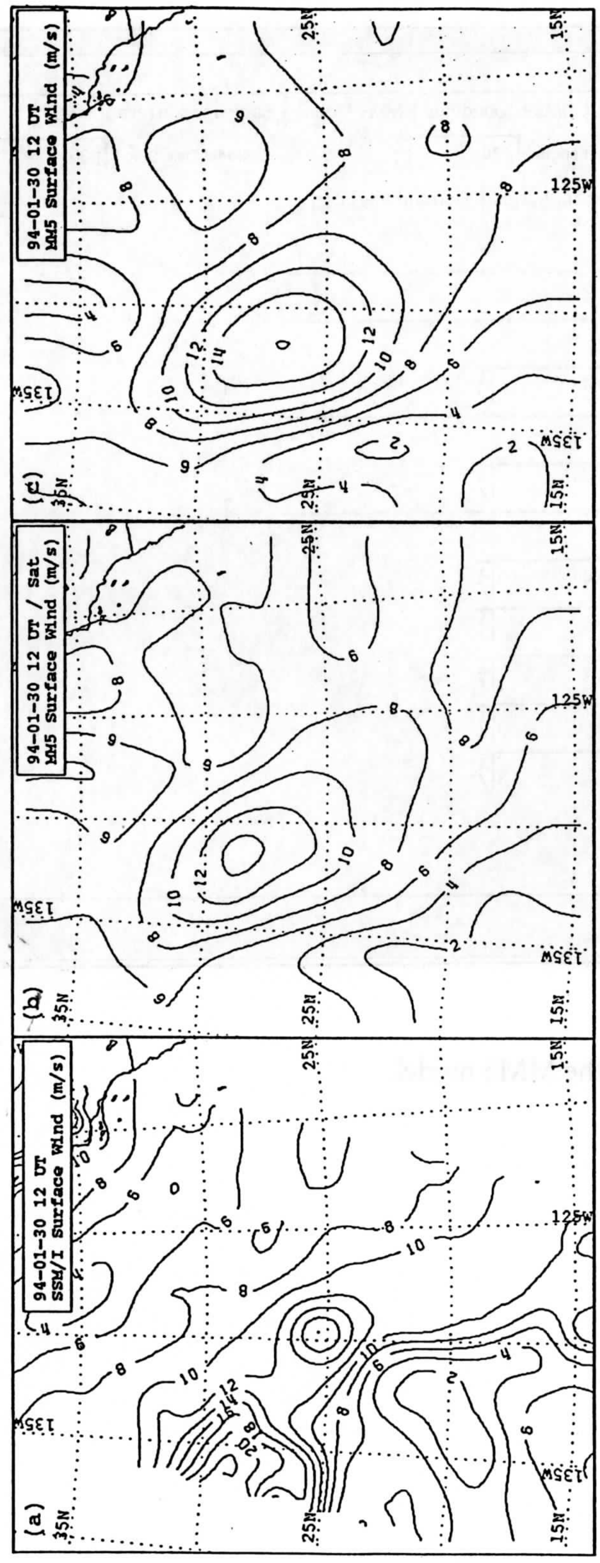

Figure 4. Surface wind speed fields for (a) DMSP SSM/I derived data, (b) MM5 initial field computed using NCEP analysis with temperature and relative humidity profiles derived from SSM/T1 and SSM/T2 measurements, and (c) MM5 initial field computed using NCEP analysis only.

maximum wind speed at the west side of the figure is outside the SSM/T1 pass coverage. However, use of the satellite sounder data brings the major meso-scale wind field pattern closer to that observed by an independent instrument, SSM/I, in this case.

5. REFERENCES

Grell, G. A., J. Dudhia, and D. R. Stauffer, 1994: A Description of the Fifth-Generation Penn State/NCAR Mesoscale Model (MM5).

Guo, Y. R. and S. Chen, 1994: Terrain and Land Use for the Fifth-Generation Penn Sate/NCAR Mesoscale Modeling System (MM5): Program TERRAIN. NCAR Technical Note/TN-397+IA, NCAR, Boulder, Co.

Haagenson, P. L., J. Dudhia, G. A. Grell, and D. R. Stauffer, 1994: The PennState/NCAR Mesoscale Model (MM5) Source Code Documentation. NCAR Technical Note/TN-392+STR, NCAR, Boulder, Co.

Manning, K. W. and P. L. Haagenson, 1992: Data Ingest and Objective Analysis for the PSU/NCAR Modeling System: Programs DATAGRID and RAWINS. NCAR Technical Note/TN-376+IA, NCAR, Boulder, Co.

Rigone, J. L. and A. P. Stogryn, 1977: Data processing for the DMSP microwave radiometer system. Proceedings of the Eleventh International Symposium on Remote Sensing of the Environment, University of Michigan, 1-10.

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