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USING IOWA ENVIRONMENTAL MESONET (IEM) DATA TO ASSESS THE EFFECTS OF SMALL-SCALE VARIATIONS IN SOIL MOISTURE AND SOURCES OF ERRORS IN PRECIPITATION FORECASTS

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1. INTRODUCTION

The Iowa Environmental Mesonet (IEM) is a network of over 300 environmental monitoring stations state-wide. High resolution data from this network were used to quantify the effects of small-scale heterogeneities in soil moisture and soil texture on the boundary layer. In addition, IEM data has allowed for the study of the atmospheric water budget to better understand sources of errors in precipitation forecasts.

One simulation of a warm season precipitation event and four simulations of post-precipitation events over the Upper Midwest were performed using a workstation version of the National Centers for Environmental Prediction (NCEP) Eta model with ten kilometer grid spacing. Four simulations were initialized at 12 UTC, one at 00 UTC, and all of the simulations were integrated over a 24 hour period over a 1000 km x 1000 km domain. For initialization and boundary conditions, output from the 40 km NCEP Eta model GRIB files were used. When atmospheric data from the 40 km Eta model were not available, output data from the 80 km NCEP Eta model were used instead.

Where NCEP's Eta model did a poor job in the representation of the initial soil moisture field, adjustments were made using precipitation data from the IEM aided by regional radars. The effects of these adjustments were then studied. In addition, a more accurate representation of soil texture was incorporated into the 10 km Eta model (Miller, 2002) and the effects of these adjustments were also studied.

To better understand sources of errors in precipitation forecasts, a water budget analysis was performed using the 10 km Eta model and observations. The model's total water mass, water vapor flux, precipitation and evapotranspiration were examined along with observed evapotranspiration and precipitation. Water vapor fluxes were calculated with the 20 km RUC analyses GRIB files and were assumed to represent the observed water vapor fluxes.

2. CASE STUDY: 22 JULY 2002

The 22 July 2002 case was chosen because large contrasts in soil moisture from recent rainfall events existed, and there were no synoptic surface fronts within Iowa to dampen any effects of small-scale heterogeneities in soil moisture and soil texture. Since the majority of the rainfall on this day occurred prior to 12 UTC, the 10 km Eta model was initialized at 12 UTC 22 July 2002.

2.1 *Synoptic Overview*

During the evening of 22 July 2002, a surface cold front and associated squall line pushed into northwestern Iowa. By 12 UTC 22 July 2002 the front had settled into central Iowa and was oriented northeast to southwest from central Wisconsin to northeastern Kansas. Scattered precipitation was located along and just ahead of the surface cold front in central and eastern Iowa. See Fig. 1 for the satellite-radar composite image at 12 UTC 22 July 2002. Winds across Iowa were out of the north-northwest at about 5 knots and temperatures ranged from the low 60's in the north to near 75 °F in the south. By 00 UTC 23 July 2002, the cold front was situated over northern Illinois and extended southwestward into central and southern Missouri. Winds throughout Iowa at that time remained out of the north-northwest at 10 to 15 knots while temperatures were near 80 °F.

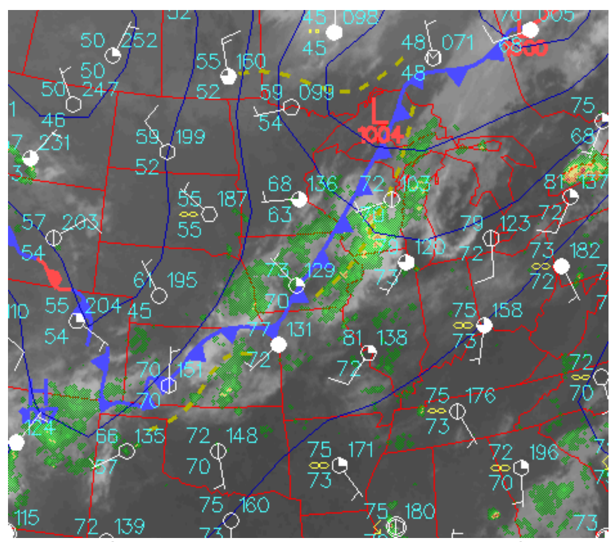

Figure 1. Satellite-radar composite image at 12 UTC 22 July 2002.

2.2 *Soil Moisture and Soil Texture*

To adjust the soil moisture fields appropriately, it was necessary to estimate the response of volumetric soil moisture to rainfall. To do this, soil moisture data from the Soil Climate Analysis Network (SCAN) site in Ames, IA were compared with several rainfall events at the same location. This site measures volumetric soil

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moisture at approximately 5, 10, 20, 50 and 100 cm within the soil. Volumetric soil moisture at 5 cm was used because it responds more readily to rainfall than any other level. Based on several rainfall events it was estimated that 25.4 mm of rain increases the volumetric soil moisture by 0.5% assuming soil becomes saturated at 43%. If rainfall amounts exceed 12.7 mm, it was assumed half will increase the volumetric soil moisture while the other half will be runoff.

On this day, rainfall amounts ranged from 25 to 50 mm in the northern and western half of Iowa with lighter amounts in the eastern part of the state. After a detailed analysis of rainfall measurements from the IEM and regional radars, it was concluded that NCEP's initial soil moisture field, used in the initialization of the 10 km Eta model, captured all the details of this rainfall event so no adjustments were necessary.

Although no adjustments were made to increase the soil moisture there was a desire to run the model with a dry soil. This, in effect, would ignore the rainfall event that occurred between 00 UTC and 12 UTC 22 July 2002. This meant initializing the Eta model with the 00 UTC soil moisture field instead of the one at 12 UTC. For the remainder of this case study, the simulation that used the 00 UTC soil moisture field will be known as the dry simulation and the simulation that used the 12 UTC soil moisture field will be known as the wet simulation.

The wet simulation with the soil texture adjustments was closest to the real observations. The most obvious impact was on the surface dew point temperature and can be seen from the time series plot of near surface dew point temperature in Fig. 2. Interestingly, the wet simulation without the soil texture adjustments was very close to the dry simulation with the soil texture adjustments (Fig. 2).

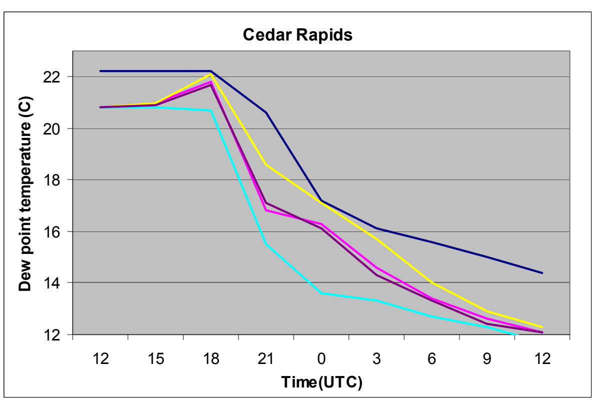

Figure 2. Time series plot of near surface dew point temperature for Cedar Rapids, Iowa beginning 12 UTC 22 July 2002 and ending 12 UTC 23 July 2002. The observed dew point temperature is plotted as the dark blue line. The yellow line is the wet simulation with the soil texture adjustments. The pink line is the wet simulation alone. The purple line represents the dry simulation with the soil texture adjustments while the light blue line represents the dry simulation alone.

3. CASE STUDY: 10 JUNE 2002

A case on 10 June 2002 was chosen for a water budget analysis since the 10 km Eta model poorly simulated the rainfall event that affected a wide portion of Iowa.

3.1 *Synoptic Overview*

During the early morning hours of 10 June 2002, an area of precipitation originating in northern Missouri moved northward into central Iowa by 12 UTC. At that time, a surface warm front was situated in northern Minnesota and Wisconsin while a surface cold front extended from South Dakota into western Nebraska. Winds were from the southeast at about 10 knots throughout Iowa with temperatures in the low 70's (See Fig. 3).

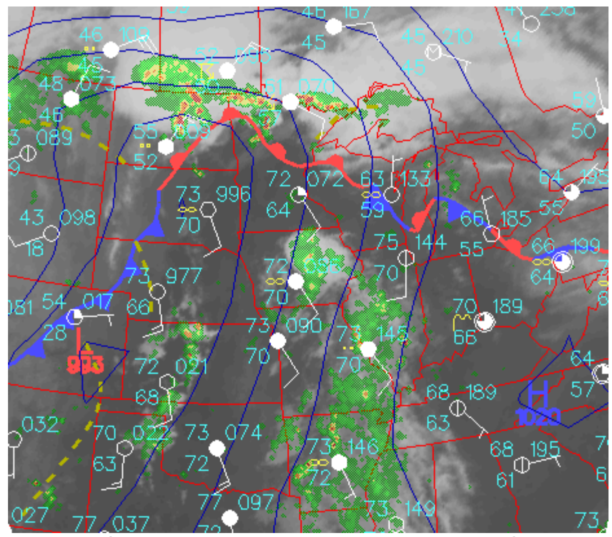

Figure 3. Satellite-radar composite image at 12 UTC 10 June 10 2002.

By 00 UTC 11 June 2002, a 996mb low was located near the North Dakota and Minnesota border with a cold front extending southwestward from the low into northern Kansas. A warm front extended north and east of the low into northern Minnesota and upper Michigan.

3.2 *Water Budget Analysis*

For this case the modeled and observed components of the atmospheric water budget were examined.

To convert pan evaporation to actual evapotranspiration, several assumptions were made. It was assumed that corn, soybeans and sorghum were the dominant crops throughout the domain. Each crop has its own crop coefficient that varies during the growing season. Collins et al. (1973), Allen et al. (1998) and Taylor (1999) provide crop coefficients for various crops and for different growth stages. Errors in estimating evapotranspiration were determined by varying these crop coefficients. For the remainder of this case study, the crop coefficients used in the first estimation of evapotranspiration will be called crop coefficient set A, and coefficients used in the second estimation will be called crop coefficient set B. In addition to pan evaporation, evapotranspiration from the 20 km RUC 1 hour forecasts was analyzed.

3.2.1 *Eta Versus Observations*

A time series of precipitation indicated the Eta model over predicted rainfall during the first seventeen hours of integration and under predicted rainfall during the last seven hours (See Fig. 4).

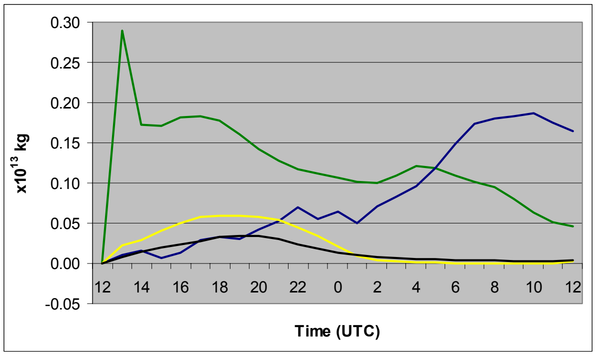

Figure 4. Time series of Eta precipitation (green), observed precipitation (blue), Eta evapotranspiration (yellow) and RUC evapotranspiration (black) beginning 12 UTC 10 June 2002 and ending 12 UTC 11 June 2002. This plot has been scaled by a factor of 10^{13} kg.

The RUC analyses revealed slight convergence of water vapor flux into the domain of integration during most of the 24 hour period while the Eta had an excess of moisture flux convergence the first twelve hours. The Eta model then exhibited moisture flux divergence from 00 UTC 11 June 2002 to 12 UTC 11 June 2002. The Eta model had more evapotranspiration than the RUC model from 12 UTC 10 June 2002 until about 01 UTC 11 June 2002 (Fig. 4). The Eta model 24 hour accumulated evapotranspiration was lower only slightly than the observed evapotranspiration estimated with crop coefficient set A. When crop coefficient set B was used, the observed evapotranspiration was closer to the Eta evapotranspiration (See Fig. 5).

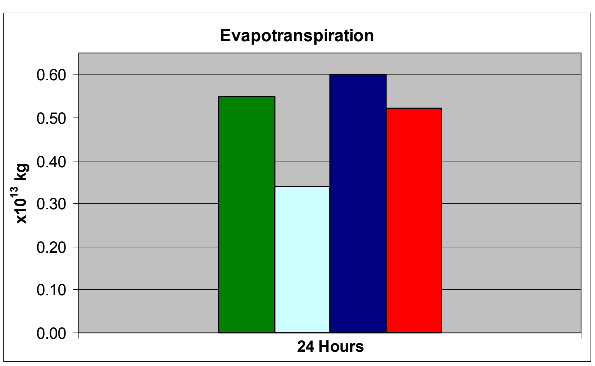

Figure 5. Bar chart of 24 hour accumulated evapotranspiration with the Eta model (green) and RUC model (light blue). Also presented is the observed evapotranspiration using crop coefficient set A (dark blue) and B (red). Evapotranspiration amounts are in kg and were factored by 10^{13} .

To better understand the differences in evapotranspiration between the Eta and RUC models the net shortwave radiation was examined. It was determined that hourly averaged domain integrated net shortwave radiation in the Eta model was lower than that in the RUC by about 15% around noontime. Horizontal plots of net shortwave radiation were then compared with visible and infrared satellite images to show that the RUC model actually placed the clouds correctly. The Eta model appeared to be too cloudy throughout most of the day. An examination of the soil moisture distribution in both models showed that the RUC model had lower volumetric soil moisture at all times. The effects of these differences in soil moisture on the Eta model water budget will be examined thoroughly.

4. SUMMARY AND CONCLUSION

From the cases presented in this study it is clear that small-scale variations in soil moisture and soil texture have some limited effects on the boundary layer. The most noticeable effect was a more accurate representation of near surface dew point temperatures when the refined soil texture was included in the wet simulation. More interesting was the over predicted rainfall early in the simulation of the Eta model for the second case and how the high volumetric soil moisture could have altered the water budget components.

5. ACKNOWLEDGEMENT

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