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Soil-water content is the single most important land-surface variable in atmospheric prediction models. Sophisticated surface physics-soil hydrology parameterization schemes are beginning to be used in mesoscale weather prediction models; however, soil-water content is not measured over large enough areas on a regular basis where it could provide suitable initial conditions for those models. Therefore, the initialization of the soil-water content profile has to depend on a knowledge of the hydrological balance of the soil in the area represented by each mesoscale-model grid point. In turn, this information must be obtained from a knowledge of the precipitation, evaporation, and substrate recharge from the water table. We have undertaken the task to develop a systematic means for providing initial values of the soil-water-content profile for the Penn State/NCAR Mesoscale Model (Anthes and Warner, 1978). This task is composed of three phases. The first phase is to develop an "off line", one-dimensional hydrological model that is driven by conventional meteorological, soil and vegetation data. The second phase is to develop the database to drive the hydrological model in a form that is compatible with the surface physics-soil hydrology parameterization scheme utilized in the mesoscale model (i.e., the Biosphere-Atmosphere Transfer Scheme (BATS), described by Dickinson et al. (1986)]. The last phase consists of generating an automated update of the soil-water-content profile at each of the mesoscale-model grid points.

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"Development and testing of improved techniques for modeling the hydrologic cycle in a mesoscale weather prediction system"

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A. INITIALIZATION OF SOIL-WATER CONTENT FOR REGIONAL-SCALE ATMOSPHERIC PREDICTION MODELS

1. INTRODUCTION

Soil-water content is the single most important land-surface variable in atmospheric prediction models. Sophisticated surface physics-soil hydrology parameterization schemes are beginning to be used in mesoscale weather prediction models; however, soil-water content is not measured over large enough areas on a regular basis where it could provide suitable initial conditions for those models. Therefore, the initialization of the soil-water-content profile has to depend on a knowledge of the hydrological balance of the soil in the area represented by each mesoscale-model grid point. In turn, this information must be obtained from a knowledge of the precipitation, evaporation, and substrate recharge from the water table.

We have undertaken the task to develop a systematic means for providing initial values of the soil-water-content profile for the Penn State/NCAR Mesoscale Model (Anthes and Warner, 1978). This task is composed of three phases. The first phase is to develop an "off line", one-dimensional hydrological model that is driven by conventional meteorological, soil, and vegetation data. The second phase is to develop the data base to drive the hydrological model in a form that is compatible with the surface physics-soil hydrology parameterization scheme utilized in the mesoscale model [i.e., the Biosphere-Atmosphere Transfer Scheme (BATS), described by Dickinson et al. (1986)]. The last phase consists of generating an automated update of the soil-water-content profile at each of the mesoscale-model grid points.

2. THE HYDROLOGICAL MODEL

The soil-hydrology model (SHM) utilized in this work is a one-dimensional, diffusion-gravitation model (Capehart, 1992). The model has three primary modules: precipitation, evapotranspiration and Darcy Motion. A maximum time step of 12 hours is required to allow two precipitation calculations (at local noon and midnight), and one evapotranspiration calculation (at local noon). The water input is represented by the precipitation, which is partitioned into three physical processes: leaf interception, infiltration, and runoff. Leaf interception represents precipitation falling on the vegetation canopy. Infiltration represents the rainfall that reaches the ground and infiltrates the top layer of the soil. If the soil is saturated, water ponds on the surface and is allowed to flow out of the domain. Once water infiltrates the top soil layer, it is distributed throughout the porous soil environment through gravitation and diffusion processes (i.e., Darcy Motion), represented by Richard's Equation (Richards, 1931). The hydraulic coefficients used by the SHM were developed by Abramopoulos et al. (1988). Diffusion processes are calculated using the Crank-Nicholson numerical technique, and gravitation processes are solved through forward-in-time/backward-in-space finite differencing.

Evapotranspiration is handled as three processes within the model domain: evaporation, transpiration, and evaporation of water intercepted by the leaves. The model domain is divided into vegetated subareas and bare-soil subareas. Evaporation occurs from the bare-soil subareas. The source of water for this process lies within the top 20 cm of the soil. Transpiration occurs through the vegetation, which removes water from the root zone. The third process only occurs when there is intercepted water on the plant canopy.

The SHM utilizes a balancing technique to generate the values of soil-water content to initialize the mesoscale model. Balancing is the process in which the forcing terms within the SHM cause simulations performed with different, random initial conditions to converge toward a single solution. This works on the premise that the SHM eventually loses sensitivity to the initial conditions and is dominated primarily by the current forcing within the model. As shown in Figure 1, the balancing period begins before the mesoscale-model initial time (t_0), using an arbitrary soil-water-content profile that is constant with depth. As the simulation proceeds through the balancing period, environmental forcings modify the soil-water-content profile so that, regardless of the arbitrary profile used to initialize the SHM, the model solutions will converge towards what can be considered to be a balanced soil-water profile. The length of the balancing period depends on the seasonal variations in meteorological and vegetation conditions and the time of year in which this process begins. If was found that as precipitation increases the soil-water content in model simulations with different initial conditions, the soil-water-content profiles rapidly converge toward a common solution. During periods of soil-water extraction, this convergence slowed or came to a halt (Capehart, 1992). Should the beginning of a balancing period occur during, or just after a water extraction period, a balancing period of several months may be required. Also, part of this period must go back to a recharge period.

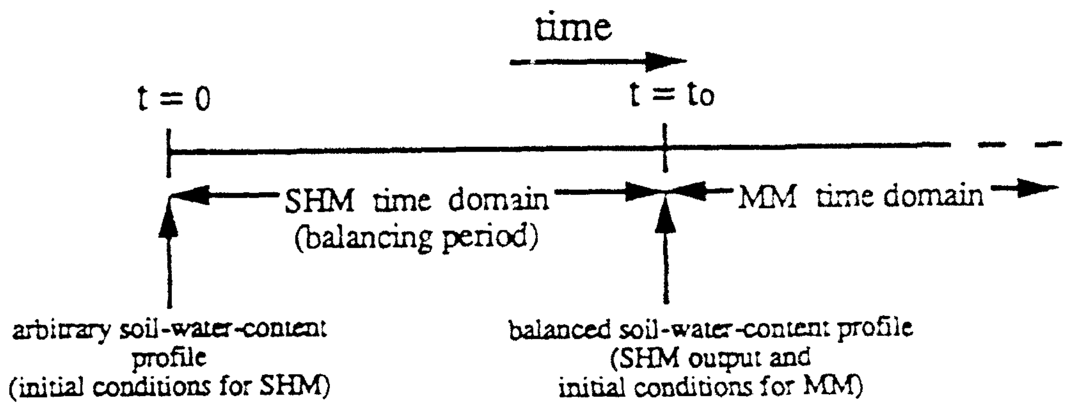

Figure 1: Schematic showing the balancing period of the SHM. MM stands for the Penn State/NCAR Mesoscale Model.

3. THE DATA BASE

The data base needed to drive the SHM is being assembled for a balancing period of four months (March 1, 1990 - July 1, 1990), on a 61 X 61 grid centered on the Mahantango Creek Watershed, with a grid spacing of 36 km (Fig. 2). This domain has been chosen as part of the Susquehanna River Basin Experiment (SRBEX) at Penn State. A schematic of the different steps required to obtain the data base is presented in Figure 3. As shown in this figure, the data base consists of three sets: the meteorological data, the vegetation data and the soil data.

National Meteorological Center (NMC) surface analyses are used as first-guess fields in the process of analyzing the meteorological data. Surface observations at three-hour intervals are blended into the first-guess fields to provide a complete meteorological dataset.

As of this writing, BATS values for vegetation and soil type are being utilized. Efforts are underway to apply the 1 km USGS EROS Data Center Land-Cover Characteristic Database to this grid. Additionally, soil data from the U.S. Department Agriculture's STATSGO Database will augment the BATS soil data as it becomes available to us.

With a complete formatted and analyzed dataset, the SHM will be run for all the grid points within the mesoscale-model domain to produce a soil-water-content profile for each grid point. Future plans include sensitivity tests to study the influence of different aggregation techniques applied to the 1 km data on the SHM results, as well the influence of the grid spacing (e.g., 36 km versus 12 km) on the SHM results.

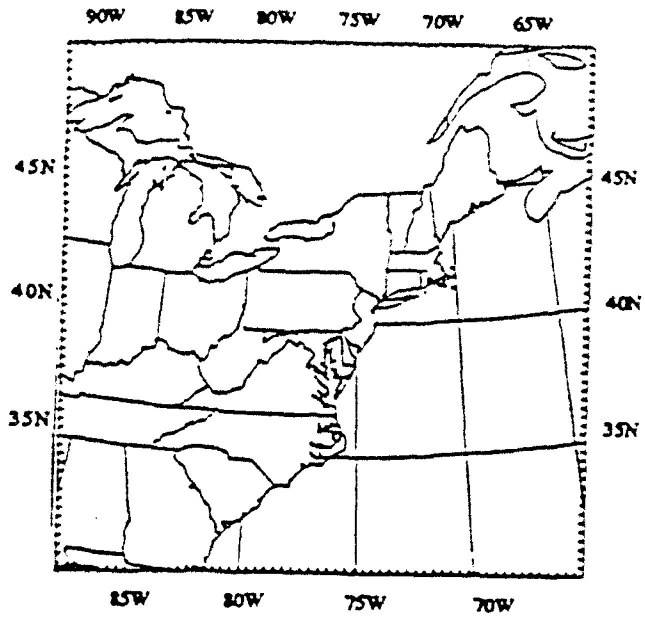

Figure 2: Domain utilized in this work.

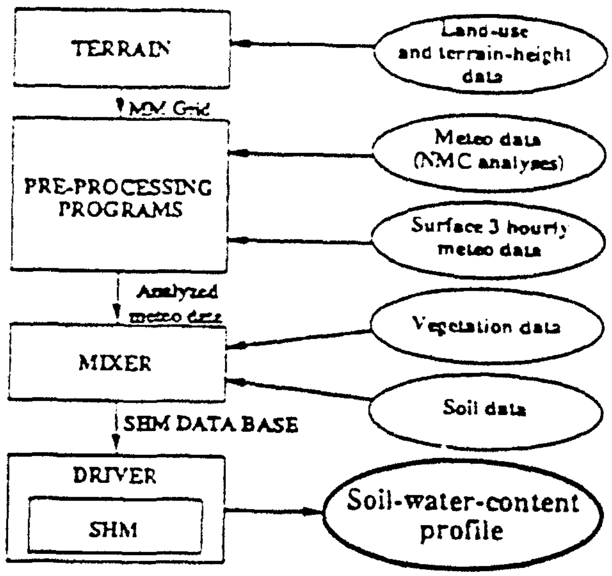

Figure 3: Schematic of the different steps required to obtain the data base for the SHM. MM stands for the Penn State/NCAR Mesoscale Model.

B: FOUR DIMENSIONAL ASSIMILATION OF RADAR-DATA IN A MESOSCALE MODEL

I. Introduction

The purpose of this research is to develop a methodology for utilizing radar observations of convective precipitation in four-dimensional data assimilation procedures of mesoscale numerical models. By using the observed timing and location of deep convection to activate a numerical model's convective parameterization scheme, convective heating and moistening profiles compatible with the model-generated environment are introduced at the right times and locations during the data assimilation period. This approach is in contrast with previously developed techniques that used artificially specified heating and moistening profiles and depended upon the model convective trigger function to initiate convection at the proper time and location. It is expected that the present approach will be able to "spin up" convectively-driven mesoscale circulations and features such as mesohighs, jet streaks, and outflow boundaries during the data assimilation period. It has been shown that these features can substantially influence numerical model forecasts but that they are difficult to initialize using convectional approaches since they are poorly observed in the present operational observing network.

II. Progress and Plans

In order to test the radar-based initialization concept, we have selected a squall line event that occurred on 10-11 June 1985 during one of the intense observation periods of the Pre-STORM Experiment (Kansas-Oklahoma). This case has been extensively analyzed and is widely documented in the refereed literature. This case has also been numerically simulated by at least three different investigators (Grell, NCAR;

Zhang, McGill; Kain, PSU) so that there is a good basis for assessing whether or not the introduction of the radar-based initialization procedures produces any improvement in the model simulation.

We have selected the coarse and fine mesh domains and designed the model structure that we will use for the model initialization experiments. We have also obtained the standard and special observations necessary to conduct the four-dimensional data assimilation tests. In particular, five radars were operating in the area in the 12 hour period from 12Z 10 June to 00Z 11 June: Amarillo TX, Limon CO, Wichita KS, Oklahoma City OK, and Monett MO. The radar observations were stored at 10 minute intervals during the 12-hour period. The complete set of data from all five radars was acquired from the NOAA Environmental Research Lab in Boulder CO. We have processed this data into the PSU computer system and have written computer code to transform the radar echo coordinate locations from all five radars in the observing network to the model domain coordinates. We have also defined criteria for when to force the implicit convection in the model. Specifically, a fine mesh model grid element (Δx = 25 km) with a reflectivity of 40 dBz or greater anywhere within the grid element is considered to be "convectively active".

Much of the computer code necessary to force the model implicit convection to be compatible with the radar-observed convection has already been written. The remaining portion of the code is expected to be completed early in year two of the project. Upon completion of this code, we will begin preliminary numerical experiments to test the reaction of the model simulation to the observation-based convective forcing. These preliminary numerical experiments will then be followed by the full-physics four-dimensional data assimilation sensitivity experiments to quantitatively assess the impact of the new initialization procedure.

C. REFERENCES

Smith, C.B., M.N. Lakhtakia, W.J. Capehart, and T.N. Carlson, 1993: Initialization of soil-water content for regional-scale atmospheric prediction models. American Meteorology Society Annual Conference, 18-22 January, Los Angeles, California.