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SEVERE STORM

FORECAST SYSTEMS

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During the contract period two basic research tasks were undertaken: first, the improvement and enhancement of an existing mesoscale numerical simulation system and second, numerical diagnostic studies associated with an individual case of severe storm development.

There were five areas in which the mesoscale numerical simulation system was improved. Probably the most critical improvement was made possible with the arrival in March, 1980 at the Langley Research Center of the CDC CYBER-203 computer replacing the CDC STAR-100 computer. With this new machine it is now possible to significantly increase the size of the matrices used in the numerical simulation model. With the in-core storage increasing from 500,000 to 1,000,000 64-bit words it was possible for us to double the model matrix sizes by changing the x and y-space dimensions from 90 and 64 to 128 and 90, respectively. This increase in matrix size from 5,760 to 11,520 32-bit words enables us to run the numerical simulation system over an area equivalent to the continental United States, northern Mexico, and southern Canada when we employ a 38.1 km grid mesh. This will, of course, greatly extend the useful simulation (forecast) period from approximately 12 to between 18 and 24 hours. When we "nest" down to finer mesh lengths, i.e., 19.05 and 9.525 km, the implications of this larger matrix are further amplified by extending each area of coverage and therefore increasing the simulation (forecast) periods at each of these scales as well. A bonus associated with the arrival of the CDC CYBER-203 computer was the system's capability for a five-fold increase in "scalar" computing-speed. While the numerical model is efficiently coded, i.e., dominated by vector processing, the increased scalar processing speed was still critically important in enhancing the speed with which the model simulation was processed. This was so because even the relatively minor amount of scalar computing was extremely slow on the STAR-100. Thus, even with the doubling of the two-dimensional matrix sizes, there was only a 20-30 percent increase in total running time of the model due to the elimination of the significant overhead caused by scalar processing.

A second critical area of improvement involves the use of mandatory and significant level radiosonde information in the initialization process of the numerical simulation model. Previously we had been using only the National Weather Service's Limited Fine Mesh analysis geopotential height, temperature, and dew point temperature information vertically-spaced on mandatory pressure level surfaces to initialize the simulation model. Since this information is analyzed only on the 1000, 850, 700, 500, 400, 300, 250 and 200 MB surfaces there is a great deal of information which is not included from the radiosonde reports which could be used to enhance the vertical structure in the model's initial state. This vertical structure is particularly crucial over the great plains and front range of the Rocky Mountains where relatively shallow and very well-defined inversion layers play a key role in establishing the hydrodynamical and thermodynamical environment leading to severe storm development. Often as many as 15 additional significant levels of data are available in a radiosonde report and this can occur in as many as 70 radiosonde reports on a given day. We use this information by constructing interpolated levels of information in the vertical every 25 MB from 1000 to 500 MB based on the Limited Fine Mesh Analysis. We then combine this information with the significant level radiosonde information by applying a standard analysis technique. We then interpolate to the simulation model's terrain— following surfaces from this vertically— denser hybrid analysis yielding a more comprehensive vertical structure of the atmosphere. Presently we are using this process through the 500 MB level only because most of the numerical model surfaces are below that pressure level. In the future this technique will be extended to 150 MB as the number of vertical levels increases in the numerical model above 500 MB.

With this increased low-level vertical data resolution also comes a requirement for improved surface data. Since the model has excellent vertical resolution in the boundary layer with levels at 250, 500, 750 and 1000 meters above the earth's surface the addition of surface information could result in a more complete vertical profile of boundary layer dependent variables. Presently the source of surface data readily available from the Water and Power Resources data base are service A surface station reports of temperature, pressure, wind speed and direction, as well as dewpoint temperature. Because we do not yet have implimented a dynamical initialization technique that enables us to use both wind and mass information we are restricted to use the surface dewpoint temperature only. In the future we will be using all available surface data. The surface dewpoint is used at initialization time by inputting approximately 250 service A reports of dewpoint temperature from surface observing stations between the Rocky Mountains and the Mississippi River and between the borders of Canada and Mexico. Basically this surface dew point temperature observation is built into the vertical lapse rate structure and then interpolated horizontally such that it modifies the initial dew point observation at the surface at each Limited Fine Mesh analysis grid point before data is interpolated to the 38.1 km matrix.

The fourth improvement to the numerical simulation system concerns the development and implimentation of a nested grid algorithm. This algorithm is designed to give us the capability to specify a region in which the hydrodynamical and thermodynamical mesoscale structure is being optimized for the development of severe local storms. By combining hydrodynamical and thermodynamical forcing functions such as the time tendency of velocity convergence, the moist static stability, and relative humidity we can determine in space and time the optimal region for "building" a finer-scale simulation mesh. More specifically, what we do is to "freeze" the dependent variables centered upon the region where the nesting index reaches a critical preset threshold value and interpolate the data to one-half the previous grid mesh length. This new data set then becomes the initial state for a shorter time period and higher resolution simulation in an effort to better define the environment where severe storms may best develop. This process of establishing a new data set will continue as long as the index threshold is exceeded thus selecting the best candidate for a simulation with a 19.05 km grid mesh. The index threshold is tested every hour for a relative maximum value. The same process is initiated during the course of the 19.05 km grid mesh scale simulation for an even shorter period but higher resolution simulation at 9.025 km. The test is done every 30 minutes for the 9.025 km simulation. Typically, the 19.05 km simulation is run to six hours of real time and the 9.025 km simulation to 2 hours of real time.

The fifth and final significant improvement to the numerical simulation system concerns the linking of the simulation output to a sophisticated and very useful graphics software package. This package accesses a group of display routines resident on the Langley computer system which enables us to project several critical fields for mesoscale and severe storm potential forecasting onto a relocatable geographical background which is highly detailed. The inherent flexibility in this software enables us to contour output fields with a variable contour interval and number as well as enabling us to modify the geographical display by projecting place names at the appropriate latitude and longitude. Such a package virtually eliminates any ambiguity that might exist in associating a simulated field with its geographical position and is extremely practical in facilitating the rapid assimilation by users of any model product.

While the research and development effort was underway to improve the numerical simulation system an effort was also undertaken to study the dynamical adjustments associated with a case of severe storm development. The case selected was April 10, 1979. There were two prominent reasons for selecting this case. First, it was an extremely severe outbreak day in which several large tornado-producing thunderstorms caused extensive loss of life and property in the Red River Valley region of Texas and Oklahoma. Second, an unprecedented amount of observational data existed for comparison with model simulations. This data was available durint the spring of 1979 as a result of the SESAME data gathering experiment which was undertaken over the southern and central plains states, the Mississippi, and the Missouri River Valleys. Probably the most useful information made available to researchers were three-hourly radiosonde balloon releases which could give us a dramatically improved picture of the three-dimensional atmospheric structure in the vicinity of the severe storm occurrences. Such information, which is, of course,far superior to the normal radiosondes taken every twelve hours can tell us much more about the evolving three-dimensional atmospheric structure before and during the tornadic storms and tell us to what extent the numerical simulation system was capturing this evolution. With this information available we could compare a variety of model-simulated and three-hourly observed dynamical fields such as: velocity convergence, vorticity, moist static stability, equivalent potential temperature, individual wind components, surface pressure, and many others. We could also examine more closely individual terms in such critical dynamical equations as the Navier-Stokes, divergence, pressure-tendency, and vorticity equations in an effort to sort out the more subtle adjustments which lead to the evolution of the important observed features on that particular day. As an example, during the period immediately proceeding the onset of tornadic activity a very pronounced mesoscale surge of southerly momentum is observed to develop southeast of the tornadic region. The existence of this feature is indisputable and is well-documented from the SESAME data sets. By studying these data sets from the perspective of a complete diagnostic and dynamical breakdown of dominant terms in the previously mentioned equations and then comparing them to a similar breakdown in the model simulation we can gain insights into the imbalances which lead to the development of this feature and to what extent the model improvements can enhance the accuracy with which we simulate it. The southerly momentum surge appears to have been instrumental in producing the transport of warm moist air northward into the region of the Red River Valley. This low-level tongue of warm moist air aloft led to a drastic reduction in the vertical thermodynamical stability of the atmosphere in this region immediately prior to tornadic development. This feature also appears to have been responsible for amplifying the vertical wind shear and low-level convergence which allows the realization of the increased potential buoyancy implied by the reduction in the thermodynamical stability in this region. As model development continues we may use such an ideal test case as a control to examine the implications of each new addition to the modelling system.