N O T I C E

THIS DOCUMENT HAS BEEN REPRODUCED FROM
MICROFICHE. ALTHOUGH IT IS RECOGNIZED THAT
CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED
IN THE INTEREST OF MAKING AVAILABLE AS MUCH
INFORMATION AS POSSIBLE

SEVERE STORM

FORECAST SYSTEMS

M. Kaplan and J. Zack
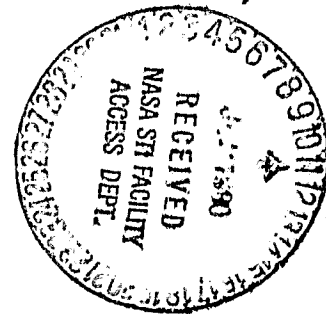
Contract NAS1-15660

Final Report

May 1980

Prepared for:

Langley Research Center
National Aeronautics & Space Administration
Hampton, Virginia 23665

Submitted by:

Systems & Applied Sciences Corporation
17 Research Drive
Hampton, Virginia 23666

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

1

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 compre-

hensive 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 avail-

able 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 ob-
servation 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 thermo-
dynamical 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

4

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 informa-
tion available we could compare a variety of model-simulated and
three-hourly observed dynamical fields such as: velocity conver-
gence, 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, diver-
gence, 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

6

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 develop-
ment 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.