

# Special Proposal for Computing Resources

*Submitted to the*  
National Center for Supercomputing Applications

*In support of*  
CAPS' Spring 1999 Special Operational Period

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## **1. Overview and Purpose**

The severe weather that occurs each year across the Great Plains causes billions of dollars in losses each year as a result of damaged property and lost productivity. This spring, CAPS proposes a Special Operational Period (SOP-99) in which its Advanced Regional Prediction System (ARPS) will be used to forecast such storms in real time. This project builds on earlier successes, notably AMS-99, in which CAPS generated numerical forecasts during one week in January 1999, as part of the American Meteorological Society's Annual Meeting in Dallas. During that highly successful project, forecasts at several different resolutions were generated on a dedicated 128-processor Origin-2000 provided by NCSA.

*CAPS proposes to again partner with the NCSA during the spring severe weather season (April 13–June 4) by running its ARPS model and associated software on Origin-2000s at NCSA.* The configuration will be similar to the AMS-99 project, but with notable enhancements based on knowledge gained during that project. First, we will be using full base NEXRAD data from four and possibly more radars in Oklahoma, Kansas and Texas. This will be the first time that velocity and thermodynamic quantities will have been retrieved from multiple radars in real time and used to initialize a numerical forecast model.

Second, the forecasts will receive increased national visibility. CAPS has been disseminating its products to American Airlines as well as federal agencies and the media in the region. (American Airlines, a major corporate partner of CAPS, uses the CAPS numerical forecasts in its daily operations). During SOP-99, meteorologists across the nation will be encouraged to view the forecasts. We will be advertising the availability of the forecasts to all National Weather Service offices, major airlines, military installations, the Federal Aviation Administration, and other agencies.

Third, CAPS scientists have been and continue working closely with NCSA and SGI specialists (e.g., K.V. Rao, Faisal Saied, Nathan Wichmann) to further improve the model's performance. For example, recent changes in the cloud microphysics scheme alone, which involved the removal of some 40 temporary arrays within certain types of loops, yields a 40% performance improvement for large grid sizes. Coupled with the possibility of using a 256-

processor Origin-2000, this offers the potential for running domains that are larger and more finely resolved than during AMS-99. Scenarios based on using 128- and 256-node machines are presented below. Other objectives remain unchanged from AMS-99. We will continue to run very high resolution (3 km) storm-resolving forecasts as well as multi-member national ensembles.

This effort is being sponsored by the National Science Foundation, American Airlines, the University of Oklahoma, the Oklahoma State Regents for Higher Education, and SGI/Cray, and *we seek herein to add the NCSA as a major partner through the provision of computing and scientific resources. In so doing we will highlight NCSA's facilities and capabilities, describe the execution of the forecast system on the NCSA Origin 2000, and use the NCSA logo (with permission) in all promotional materials.*

This document outlines briefly the methodology to be used in creating and delivering the forecast information, as well as the computing resources required. *One unique aspect of this effort is that, as with AMS-99, it will demonstrate a new capability at NCSA — the provision of dedicated blocks of resources to support very complex, massively parallel fluid dynamics models that demand real time execution for operational demonstration and evaluation.*

## **2. Proposed Forecast Configuration**

The numerical forecasts will be generated by the CAPS Advanced Regional Prediction System (ARPS), which is an end-to-end, fully automated forecast system designed for massively parallel computers and for assimilating data from high-resolution observing systems such as Doppler radars. The ARPS has been tested operationally during the past 5 years in collaboration with the National Weather Service, private companies, and foreign and domestic governments, and for these efforts CAPS received in 1997 both the *Discover Magazine* Award for Technological Innovation and the *Computerworld-Smithsonian* Award. During the 1999 AMS Annual Meeting CAPS demonstrated new forecast system capabilities, such as ensemble prediction and the use of real-time Doppler radar data, to its peers around the world, highlighted the use of this capability by a commercial airline, and showcased the capabilities of an NSF supercomputing center in supporting the computationally intensive and dedicated resource requirements of real-time numerical weather prediction.

The forecast domains prepared for use during SOP-99 are shown in Figure 1 and detailed in Table 1. The primary emphasis is on the prediction of high-impact weather in the 9 and 3-km grids over the southern Great Plains. However, the forecast demonstration will also involve the creation of ensemble forecasts over the continental US (30-km grid in Figure 1). In ensemble forecasting, several forecasts are generated for the same time period from slightly different initial conditions and then statistically averaged to obtain a mean forecast, along with the spread (variance) and conditional probabilities of specified quantities (e.g., accumulated rainfall exceeding a given threshold). In this manner, ensemble forecasting seeks to account for the uncertainty inherent in the initial state of the forecast model (due, for example, to the poor spatial and temporal resolution of observing systems), for which nonlinear growth can lead to diverging solutions and thus different forecast outcomes.

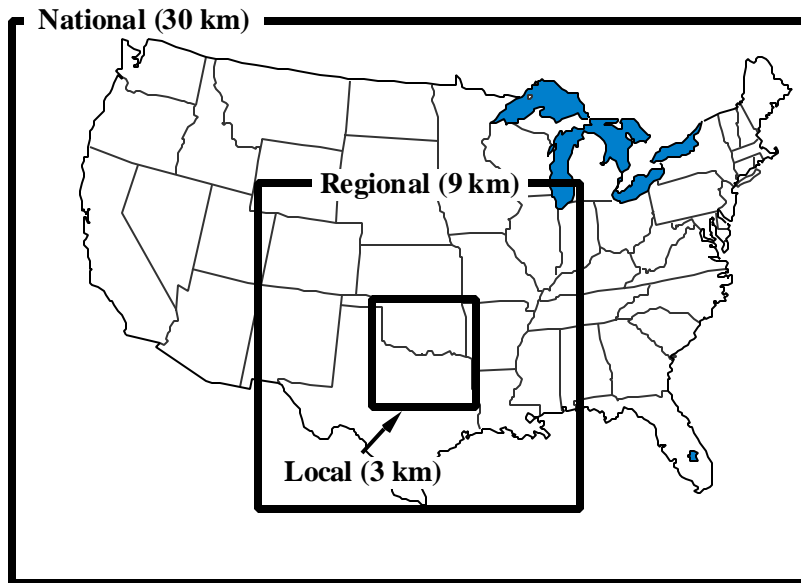


Figure 1. Forecast domains (spatial resolutions in parentheses) to be used during SOP-99 (see Table 1). The National grid will be used for ensemble forecasts, while single, overlapping (in time) forecasts will be generated on the two inner grids. The grids are based on Configuration A.

In Table 1, two potential configurations are listed. Configuration B is similar to that used during AMS-99. Configuration A, the preferred configuration, uses a 256-processor machine to achieve much finer vertical resolution and slightly larger domains. The computational requirements of these configurations are discussed in the following section.

Table 1. Forecast system configuration for the 1999 AMS Annual Meeting, based on a 256- or 128-processor machine. The number of grid points does not include 3 artificial boundary zones in each dimension

Grid	Region	Δx (km)	Grid points (nx × ny × nz)	
			Configuration A (256 processors)	Configuration B (128 processors)
National	Continental U.S.	32	170 × 120 × 50	160 × 110 × 40
Regional	Central/Southern Great Plains	9	216 × 216 × 50	198 × 198 × 40
Local	N. TX, OK	3	216 × 216 × 50	198 × 198 × 40

The ARPS was extensively optimized during the last half of 1998. The code used during AMS-99 runs at 80 MFLOPS on a single 195-MHz processor. For a fixed problem size per processor, the extra overhead for running the MPI version of the ARPS is 20% on 32 processors, 50% on 120 processors, and 110% on 225 processors. Current optimization efforts are focusing on improving cache performance via pre-fetching and more effective use of shared memory.

### 3. Computing Resource Request

The proposed forecast demonstration, for which we request dedicated time, will take place from 13 April–4 June 1999. *Some dedicated time during the week prior to the start of the formal prediction period will be needed for final testing and tuning.* In order to avoid Internet bottlenecks, nearly all pre- and post-processing (graphics) will also be performed at the NCSA. The resulting web documents and images will reside on an NCSA server, and the CAPS web-based decision support system will be used to display all forecast products, as was the case during AMS-99.

#### *a. CPU Requirements*

Based on experience during AMS-99, as well as the possibility of using a 256-processor machine, we present two potential configurations. The first configuration (A), which we prefer, takes advantage of the larger machine by using finer grids and larger domains than were employed during AMS-99 (Table 1). A total of 9.0 wall-clock hours is requested, distributed among 3 time blocks. The second configuration (B) uses the more modest AMS-99 grids. Most of the computation (8 hours) is done on 128 processors, although 32 processors will suffice for one of the runs (1.5 hours).

*Table 2. Forecast system configuration for the 1999 Special Operational Period. Two configurations are presented; they differ in the number of processors required.*

#### *Configuration A: 256 Processors*

<b>Run Name</b>	<b>Forecast Length (hours)</b>	<b>Run Time (CDT)</b>	<b>Wall Clock Time (hours)</b>	<b>Number of Processors</b>
00Z National Ensemble	36	0100–0300	2.0	256
12Z National	24	1000–1100	1.0	256
16Z Regional	12	1100–1300	2.0	256
18Z Storm	6	1300–1500	2.0	256
21Z Regional	12	1600–1800	2.0	256

#### *Configuration B: 32–128 Processors*

<b>Run Name</b>	<b>Forecast Length (hours)</b>	<b>Run Time (CDT)</b>	<b>Wall Clock Time (hours)</b>	<b>Number of Processors</b>
00Z National Ensemble	36	0100–0300	2.0	128
12Z National	24	0830–1000	1.5	32
16Z Regional	12	1100–1300	2.0	128
18Z Storm	6	1300–1500	2.0	128
21Z Regional	12	1600–1800	2.0	128

### ***b. Disk Usage and Other Requirements***

We request 30 Gb of online scratch disk space that will remain online for several hours before purging in case a restart is needed. We request 20 Gb of *permanent* disk space for work space, including ARPS boundary data needed for nested grid runs, as well as the web pages. The forecasts will generate a total of about 18 Gb per day of data, which we will archive on the mass-storage system daily.

We would like to be able to run these jobs interactively (via crontab), as was the case during AMS-99, as opposed to using the queues, because of the complexity of the interactions among the various ARPS executables.

As during AMS-99, we would like to have key software that normally resides on shared disks, such as NCARGraphics, physically reside on all of the machines we will be using. This is to minimize the possibility of disruption due to NFS problems.

Finally, we request that the latest stable version of Perl be installed on all of the machines we will be using. The version on modi4 5.003 does not contain certain bug fixes and features that we need.

### ***c. Timetable***

By 29 March 1999	Begin installing and testing new configuration at NCSA.
By 6 April 1999	Establish final forecast system configuration. All graphics and web systems in place.
By 9 April 1999	Radar retrieval system fully tested.
13-14 April 1999	Dedicated queues begin operation. Full scale production testing begins and final configuration is certified ready for use.
15 April - 4 June	Daily production forecasts