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THE NMC PRODUCTION SUITE

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GENERAL DESCRIPTION: THE PRODUCTION SUITE

The suite of production computer jobs which ingests meteorological information, analyzes it, and predicts the future state of the atmosphere for world-wide distribution comprises a number of sub-suites, or "runs". These runs, although differing in purpose and content, have much in common: each includes establishing analysis/initial conditions describing the current state of the atmosphere, forecasting the future state, and making the analysis and forecast information available to a wide assortment of users both inside and outside of the NWS. There are six such runs; all but one are repeated twice per day, using observational data taken at or near the synoptic time of 0000 hours UTC (00Z), and again using data taken at 1200 hours UTC (12Z). These are referred to as the 00Z and 12Z "cycles" respectively. One of the runs also makes use of 06Z data (in the 00Z cycle) or 18Z data (in the 12Z cycle).

Each of the six runs comprises many jobs, some making highly technical meteorological computations, others making complex graphical calculations, and others collecting and formatting observed data, preparing bulletins for external transmissions, and archiving data, analyses and forecasts for future needs. Indeed, a great part of the time in the runs is taken up with the generation of products for displaying and disseminating meteorological information. The six runs are named either by their relative position within each cycle (Early or Final), or by their general purpose (Regional, Aviation, Hurricane, or Medium-Range Forecast).

Reference to a run is made by using the name of the "Network", a system software device that controls the execution sequence of individual jobs: ERL (Early), RGL (Regional), AVN (Aviation), HCN (Hurricane), MRF (Medium-Range Forecast) and FNL (Final) are the network names of the current runs.

Because NMC's numerical analysis and forecast systems are undergoing steady change and evolution, the scheduled times at which the various runs begin are subject to change. The table at the end of this section summarizes the current configurations of the runs. The table indicates the run and network names, the analysis system used, the forecast model, the data cutoff

time, and the time period of the forecasts generated in each run. The "System Designation" is another common name that denotes the particular analysis and forecast models used in the run.

The data cutoff times in the table are approximate; they indicate the times when sufficient data to start the run in question have normally arrived at NMC. On those occasions when difficulties occur (telecommunications problems, machine hardware problems, whatever) the data cutoff may be delayed to wait for critical data or machine availability. NMC's Senior Duty Meteorologist (SDM) has the responsibility for decisions such as how long to wait, whether to use the backup procedures, which forecast to use for the analysis first guess, and the like. Because NMC works on rather tight schedules, delays in one run may introduce additional delays in subsequent runs. The SDM must take this into account as well.

Preliminary to running the suite described below in each cycle, a collection of start-up jobs are run to accomplish an assortment of necessary tasks. These include initializing various files and data sets, archiving data from the previous cycle, running a collection of verification codes and, most importantly, setting up the first guess for the analyses to be done in the upcoming runs. These jobs all run in the "NMC" net.

THE EARLY (ERL) RUN

The first run in each cycle is the Early (ERL) run. This run has the purpose of making a forecast over the U.S. as soon as possible for early guidance to the National Weather Service and the meteorological community at large. The data cutoff time is indicated in the table.

The analysis method, originally designed by Cressman (1) and substantially modified over the years (2) since its inception, is known as the Successive Correction Method of analysis (SCM). Normally, the analysis starts with a first guess generated from the forecast of the FNL run (q.v.); the SDM, however, has the option to use the AVN run forecast if he deems that to be appropriate. Once under way, the SC program produces a set of analyses (heights, winds, and temperatures) for 10 mandatory pressure levels on a 53- and 57-point half-bedient grid (a 190.5 km mesh on a polar stereographic projection true at 60 north) covering North America and adjacent waters.

The forecast model, known as the Limited-area Fine-mesh Model (3, 4) (LFM) interpolates the analyses into a boundary layer, three tropospheric layers, and three stratospheric layers (known collectively as sigma layers after the conventional name of the non-dimensional coordinate system), takes in an analysis of moisture for each of the lowest three sigma layers of the model, reduces the grid extent to 53 by 45 points, forecasts to 48 hours and outputs meteorological information on the mandatory pressure layers on the 53- by 45-point grid, by interpolating from its sigma layers to mandatory pressure levels.

The LFM model runs on the CYBER 205; all the other codes in the run are executed on the NAS 9000 computer. The LFM has been an operational model in

one form or another since the early 1970s. The CYBER 205 version became operational on August 20, 1983; a few revisions have been made since then. The principal one was an improvement to the frictional boundary layer parameterization (5), introduced on January 9, 1985.

On the relatively infrequent occasions when the CYBER 205 computer is inoperative, a backup version of the LFM model runs on the NAS 9000. The main consequences of this are a considerable increase in the time it takes to make the 48 hour forecast and the absence of the boundary layer parameterization mentioned in the previous paragraph.

The remainder of the run comprises many jobs which generate graphical output, bulletins, and further manipulation of the forecasts, including Model Output Statistics (MOS) (6). The MOS programs take forecast parameters directly from the models and use them as predictor variables in previously derived regression equations. The results are an assortment of weather parameters at station locations, not directly forecastable by any dynamical prediction model, such as probability of precipitation, maximum and minimum temperatures, indicators of severe weather, etc.

THE REGIONAL (RGL) RUN

The second run is the Regional (RGL) run. The purpose of this run is to produce the best possible forecasts for the U.S. area, using analysis and forecast models that fully exploit the current state of the art of computational resources. The analysis/forecast system in the run is commonly known as the RAFS, an acronym for Regional Analysis and Forecast System (7). The data cutoff time is indicated in the table.

The analysis method is a Regional Optimum Interpolation (ROI) analysis system (8) which, starting with a first guess based on the forecast from the Final run, generates initial conditions on a variable density longitude-latitude (lola) grid over the northern hemisphere. The grid has an approximately 2 degree resolution over the U.S. and environs, approximately 4 degree (staggered) resolution elsewhere. The analysis is performed in 16 sigma layers in the vertical, the same sigma layers that the Nested Grid Model (NGM) (9) uses in making a forecast. The analyses are used in an initialization step which involves interpolation into a 16 layer 80-wave spectral forecast model which in turn performs a "normal mode initialization", bringing the mass and motion fields into approximate balance. The information is then re-interpolated to an approximate 1 degree lola grid in the sigma layers, and thence to the three nested cartesian coordinate grids that the NGM uses.

The NGM forecasts in the 16 sigma layers and the three nested grids to 48 hours. The forecast grids have an approximate resolution of 360, 180, and 90 km. They are referred to as the "A", "B", and "C" grids respectively. The densest grid is centered over the U.S. and the coarsest grid is hemispheric in extent. As the forecast proceeds, output is generated for mandatory pressure levels as needed at six hourly intervals. Some of the output fields are presented on the NGM C grid; a full set of forecast information is

interpolated to the half-bedient LFM grid. The latter step makes it convenient for the graphics, bulletin makers and other codes originally written for the ERL run to generate output from the NGM forecasts.

The analysis and forecast codes run on the CYBER; all the other codes in the run (mainly those that gather up observations to be passed to the ROI or to generate maps of the forecasts) are executed on the NAS 9000. The RAFS became operational on March 27, 1985 and an assortment of minor changes have been made since.

If the CYBER is not functioning properly the RGL run is simply deleted from the production suite. There is no possibility for backup on the NAS 9000 due to the numerical and meteorological complexity of the analysis and forecast systems. In this eventuality, LFM forecast information is sent out in place of the missing NGM forecasts.

THE AVIATION (AVN) RUN

The third run is the Aviation (AVN) run. This is the first forecast in a given cycle which is global in extent. Its primary purpose is to prepare guidance material in support of NMC's international aviation responsibilities. (Domestic aviation forecasts are covered, in part, by the ERL and RGL runs.) The data cutoff time is indicated in the table; it is set to assure the arrival of adequate amounts of satellite and conventional data from the western Pacific and Southern hemisphere.

The analysis for the run is a fully global application of the multivariate Optimum Interpolation (GOI) technique (10). Using the same forecast from the Final run as in the other runs as the first guess of atmospheric structure, the analysis is done by correcting this estimate on an approximately equal area grid. In the north-south direction, the grid points have an approximate spacing of 3 degrees of latitude; in the east-west direction, there are a variable number of points, starting with 78 on the row nearest to the equator and diminishing to 4 on the row nearest the poles. This provides approximately 4.5 degree latitude spacing in the east-west direction formed on the 12 mandatory pressure levels from 1000 mb to 50 mb; however, the analysis is three dimensional in that observations at levels other than the analysis level can influence the results.

Once the analysis has been completed, the meteorological information is interpolated to the 12 sigma layers of the AVN version of the Global Spectral Forecast Model (11) and subjected to an adiabatic version of the normal mode initialization (as in the RGL run) to help bring the winds and heights into balance. The forecast, using 12 sigma layers and a 40-wave rhomboidal truncation resolution, is run to 72 hours, with the production of pressure level information at 6-hour intervals on a 65- by 65-point one-bedient grid, as well as in spectral coefficient form.

The spectral model was first introduced into NMC's operations in August 1980 in a 30-wave configuration; since that time it has undergone a number of changes and improvements, primarily dealing with the number of waves carried

in the spectral representation and the number of layers used for the longer range portions of the forecasts. The spectral resolution grew from 30 to 40 waves with the availability of the CYBER machine; this change was introduced in October 1983.

When the CYBER is out of commission, rather less sophisticated versions of the models (an old spectral analysis method using Hough functions and a 30-wave truncation in the forecast model) are run as backup on the NAS 9000. The backup versions of the models also take longer to run, thus compounding the problem of reduced quality with delay.

The remainder of the run, as with the others, is given over to a great deal of data processing of the forecast information: map making, AFOS transmissions, and bulletin preparations so that forecast information can reach a myriad of recipients in a multitude of formats.

THE HURRICANE (HCN) RUN

The fourth run is the Hurricane run (HCN). This particular run is done on an "on-call" basis, only if there is a need for it. It is run both for hurricane tracking and, occasionally, for heavy precipitation forecasting. In either event the decision to run the model, and in which configuration, rests with the SDM, with input from the National Hurricane Center. When run, the model starts from the same analysis initial conditions as the AVN run and shares the same data cutoff time.

If the run is for hurricane tracking purposes, a first step is the placement of the initial position of a hurricane within the analysis. The model performs a "spin-up" operation to generate the mass/motion field of the hurricane. None of the current analysis systems are sufficiently fine-grained to resolve the structure of a hurricane unaided.

The forecast model, known as the Movable Fine Mesh (MFM) (12) model, has 10 sigma layers and runs on a 60 km grid with boundary conditions taken from the contemporary AVN run forecast. The forecast model is unique among NMC models in that it actually follows the hurricane as the latter is being forecast. If the hurricane moves one grid point on the model grid, the grid is relocated, keeping the hurricane at the center of the grid. The boundary conditions are then refreshed from the AVN model run. The HCN run extends to 72 hours; the usual output is a message (to AFOS) specifying the hurricane forecast track at 6-hour intervals.

The model runs on the CYBER; it first became operationally available (on an earlier machine) in 1975 and has undergone a number of evolutionary changes since then, mainly dealing with operational aspects and computer utilization. In the event that the CYBER is unavailable, an essentially identical version of the model runs on the NAS 9000 at a considerably slower rate.

THE MEDIUM-RANGE FORECAST (MRF) RUN

The fifth run, the Medium-Range Forecast run (MRF) (13) is run only in the 00Z cycle. Its purpose is to generate a global forecast of the atmosphere at the medium range time scale, generally understood to mean the 5- to 10-day range. It shares the same analysis as the Final run (see below).

The forecast model shares many of the basic characteristics of the Global Spectral Model used in the AVN run with the following major differences:

1. The model has 18 sigma layers of equal pressure thickness, rather than 12 unequal ones.

2. Radiative heating and cooling calculations have been added. The shortwave calculations are performed by the methods of Lacis and Hansen (14); the longwave calculations by the methods of Fels and Schwarzkopf (15).

3. The previously limited boundary layer processes have been replaced with those of the GFDL "E2" physics (16).

4. The "silhouette" mountains (17) have been introduced to enhance the terrain effects.

The model makes a forecast to 240 hours (10 days) with output maps generated every 24 hours. For the 5- to 10-day portion of the run, the output is in the form of 5-day mean maps; these are used by NMC's Medium Range Forecast Group in the preparation of their forecasts.

The MRF system became operational on April 17, 1985, normally running on the CYBER. If the CYBER is out of service the backup is to extend the AVN (12-layer) model forecast from its normal termination at 72 hours out to 144 hours. There is simply not enough time to go all the way to 10 days on the NAS 9000. If the CYBER goes down after passing 144 hours, no backup is attempted - we make do with what we can get.

THE FINAL (FNL) RUN

The last of the runs in any one cycle is the Final (FNL) run. This run serves the important purpose of producing the best possible first guess for the various analyses to be run in the next cycle. This is accomplished by delaying the run as long as possible so as to pick up late arriving conventional and satellite data and also by making two analysis and six-hour forecast pairs. This procedure is known as the Global Data Assimilation System (GDAS). The data cutoff times are indicated in the table. Note that the times are not symmetric; the difference is to allow time for the MRF run in the 00Z cycle.

The analysis system used for the FNL is identical to that used in the AVN run.

The forecast at the present time is made with the 12-layer 30-wave spectral model; however a change to the 18-layer 40-wave model with additional physical parameterization (the model used in the MRF run) is scheduled for implementation in the winter of 1985-86. The table, anticipating things a bit, reflects this change.

The use of an analysis-forecast system as a mechanism to supply the first guess for subsequent analyses has been around almost since the beginnings of numerical weather prediction. Historically the FNL run has been a testing ground for new models and changes of substance to old ones, in both the analysis and forecast portions of the run. The current FNL configuration dates from August 1982. The FNL is run on the CYBER, excepting, as usual, the collection of observations, and graphics generation. None of the analysis or forecast products are distributed outside of NMC. The backup, when the CYBER is down, is essentially a repeat of the AVN run analysis and forecast model, on the NAS 9000, but with the late data cutoff and the inclusion of the 06Z or 18Z analyses.

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NOMENCLATURE FOR THE NMC PRODUCTION SUITE

RUN	NET	ANALYSIS	PREDICTION MODEL	DATA CUTOFF	PREDICTION (h)	SYSTEM DESIGNATION
Early	ERL	SCM (Regional)	Limited-Area Fine Mesh (LFM)	H+1:30	48	LFMS
Regional	RGL	ROI (Regional)	Nested Grid Model (NGM)	H+2:15	48	RAFS
Aviation	AVN	GOI (Global)	Global Aviation Model (GAM)	H+3:45	72	AAFS
Hurricane	HCN	GOI (Global)	Movable Fine Mesh (MFM)	H+3:45	72	HAFS
Medium-Range	MRF	GOI (Global)	Medium-Range Forecast (MRF)	H+6:00 (00Z)	240	MAFS
Final	FNL	GOI (Global)	Medium-Range Forecast (MRF)	H+6:00 (00Z) H+9:30 (06Z) H+8:30 (12Z) H+9:30 (18Z)	6 6 6 6	GDAS

H denotes 00Z or 12Z - the principal observation time for each cycle

LFMS: Limited-area Fine Mesh System
RAFS: Regional Analysis and Forecast System
AAFS: Aviation Analysis and Forecast System
HAFS: Hurricane Analysis and Forecast System
MAFS: Medium-Range Analysis and Forecast System
GDAS: Global Data Assimilation System

Special Note: At present (January 1986) a hemispheric analysis (the Hough Analysis System) followed by a Barotropic Model Forecast to 48 hours is run as the first step in the Early run. The data cutoff time for this step is H+1:05. NMC plans to drop this analysis and forecast from operations shortly. At that time, the data cutoff for the Early run will be moved to H+1:15 and that of the Regional run will be moved to H+2:00.

CR TA 86-4
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