Annual WWW Technical Progress Report on the Global Data Processing and Forecasting System 2004

UNITED STATES OF AMERICA

1. Highlights For Calendar Year 2004

The most significant event of 2004 from an operational standpoint was the installation of Phase II of the Central Computer System, which includes, for the first time, a geographically separate backup system with full operational backup capabilities. The new computer systems use a highly parallel IBM Power-4 architecture with 1280 processors each. The new systems are expected to become operational on January 25, 2005.

1.1 The Central Computer System

The second phase of the system was installed in the IBM Gaithersburg, Maryland, computer facility in August 2004 and in the NASA IV7V facility in Fairmont, West Virginia, in September 2004. The two systems are functionally identical and can serve as either the Primary or Backup System. Each is comprised of IBM eServer Cluster 1600 pSeries 655 servers using the 1.7 GHz Power4+ CPU and IBM's High Performance Switch fabric. Each cluster contains a total of 1408 processors and approximately 22 TB of disk space, expanding to 45 TB in 2005. The two clusters are connected by a dedicated, secure, high-speed wide area network.

1.2 Winter Storm Reconnaisance Program

The goal of the Winter Storm Reconnaissance (WSR) program is to enhance the meteorological observational network prior to significant winter events. The innovative aspect of this program is that observations are adaptive in that they are collected only in areas presumed to most influence forecasts for these winter events. General forecast material and ensemble-based objective guidance are used to identify forecast weather events associated with large uncertainty. For flight planning purposes, the route selection and dropsonde areas must be selected approximately 30 hours before flight time. An ensemble application is used to evaluate all pre-designed flight tracks to assist in the selection of the site or sites expected to reduce forecast error variance the most. The program became operational at the National Weather Service in 2001. Adaptive observations are taken in each winter over a 2-month period during January-March. Results show that 60-80% of the targeted Numerical Weather Predictions (NWP) improve significantly due to the WSR adaptive observations, allowing forecasts related to significant winter weather events to be issued 12 hours earlier than without such observations.

1.3 Major changes to the NCEP Production Suite

A timeline of the most significant additions and enhancements to the NCEP production suite is provided below:

February 24, 2004: The Global Forecast System (GFS) model was upgraded at 1200 UTC to include sub-gridscale mountain blocking, which is the parameterization of the separation of airflow in the vertical with passage over mountainous terrain. The Global Forecast System mountain blocking parameterization improves the treatment of gravity wave momentum changes around sub-gridscale mountains. The scheme enhances friction to force lower-level parcels to flow around a mountain and lets upper-level parcels flow over the mountain. GFS test results (at T62 spectral resolution) show an increase in northern hemisphere skill scores and a reduction in 5-day forecast busts.

March 2, 2004: NCEP upgraded two ocean guidance models. The Global Superstructure Ice Accretion Guidance (nowcast/forecasts out to 7 days at 3-hr intervals, run 4 times per day) now includes the southern hemisphere and Antarctic danger zones, to support research supply ships and passenger vessels visiting the continent. The Open Ocean Fog and Visibility System was replaced by a new GFS-based global visibility system using the Eta visibility product algorithm. The new system is designed primarily for vessels at sea, but can also be used by aviation and public weather interests; it runs 4 times per day (up from 2) with forecasts out to 7 days at 3-hr intervals, and is no longer seasonal.

March 2, 2004: Several upgrades to the NCEP WaveWatch model were implemented at 1200 UTC. The global WaveWatch-III (WW3) model began assimilating buoy and ERS2 altimeter data, and the forecast length was extended out to 180 hours in the NOAA WW3, the Alaskan Waters (regional WW3), the Western North Atlantic (regional WW3), and Eastern North Pacific (regional WW3) models.

March 9, 2004: The Global Forecast System (GFS) Ensemble was upgraded at 1200 UTC. The upgrade includes the following: extend the forecast run at T126 spectral resolution from 84 out to 180 hours (improves ensemble support for 4-7 day forecasting, allows tropical cyclone tracking out to 7 days, and provides boundary conditions for the Short Range Ensemble Forecast out to 90 hours); add 06Z and 18Z forecast runs for 4 daily cycles (matches the 4 GFS control forecasts, and provides more ensemble members for medium-range and week-2 forecasts); and shorten the T126-resolution forecast time step from 20 to 10 minutes (improves the ensemble forecast quality by matching the GFS control time step).

March 16, 2004: The Eta model "Winter 2004" bundle was implemented. This bundle consists of assimilation of GOES cloud top radiances in the Eta 3DVAR analysis, use of daily gauge data for precipitation assimilation bias adjustment, and changes to the Eta Land-surface model so it uses the precipitation type predicted by the model microphysics. The bias adjustment applied to assimilated precipitation reduces the dry bias in the EDAS soil moisture, which was caused by the low bias in the assimilated multi-sensor (gauge+radar) precipitation analysis. Details at http://wwwt.emc.ncep.noaa.gov/mmb/briefings/EtaWinter2004.briefing.html

April 14, 2004: A package of changes to the 20-km RUC model and analysis were implemented to improve precipitation, cloud, and surface forecasts. The model changes include a modification to the vertical advection of moisture, definition of coastline land-use, and two smaller microphysics-related changes. This change improves the amount and areal coverage of precipitation, and also includes the evolution of soil moisture. The analysis change is to use PBL depth to aid the assimilation of METAR data. This change is helpful especially for more accurate surface dew point and CAPE forecasts. Documented online at http://ruc.fsl.noaa.gov/ppt_pres/RUC-Mar04change-1.htm.

April 26, 2004: The analysis changes in the April 14, 2004 RUC implementation were pulled from production due to intermittent moisture/CAPE noise in analysis fields.

April 29, 2004: The Geophysical Fluid Dynamics Laboratory (GDFL) Hurricane model was upgraded. The following changes were made: evaporate rain in large-scale condensation (implemented July 28, 2003 for the 2004 hurricane season); modify downdraft formulation in Simplified Arakawa-Schubert Scheme in the boundary layer; reduce momentum mixing in storm region; reduce threshold for large-scale condensation from 100% to 98%; extend ocean coupling to include the East Pacific Basin as well as the Atlantic Basin.

May 25, 2004: NOAA-16 HIRS/3 observations were turned off in the Global Data Assimilation System (GDAS) at 1200 UTC.

June 1, 2004: Initial implementation of the Downscaled GFS with Eta Extension (DGEX; http://wwwt.emc.ncep.noaa.gov/mmb/mmbpll/dgexhome.ops/DGEX_combined.htm). The DGEX is a small domain (Alaska at 00z/12z, CONUS at 06z/18z) Eta-12 run from 78-192 h, initialized from the 78-h North American Eta-12 forecast. Lateral boundary conditions are obtained from the 6-h old GFS forecast, updated at 3-h intervals through the 174-h DGEX forecast, and from either the 6-h old or 12-h old GFS at updated at 6-h intervals thereafter. The purpose of the DGEX is to provide NWS Forecast Offices with a mesoscale first guess to the National Digital Forecaster Database (NDFD) eight day forecast grids.

August 10, 2004: The NCEP Sea Ice satellite analysis product was upgraded. The old product has a 1/2 degree global product, and separate northern/southern hemisphere products at 25.4 km hemispheric resolution. The upgraded guidance continues to derive the old hemispheric grids, but the basis is the new higher resolution 12.7 km hemispheric analysis. The new global grid has 1/12th degree (5 minute) resolution instead of the 30 minute (1/2 degree) resolution of the old grid. The hemispheric grids are for use by sea ice scientists, and may contain weather contamination and areas where the data are older than one day. The global grid is for use by models and other users who want fields which can be used in automated processing.

August 17, 2004: The NCEP Short Range Ensemble Forecast (SREF) system was upgraded. The horizontal resolution of all 15 ensemble members (Eta and Regional Spectral Model (RSM)) increased from 48 km to 32 km. Eta member vertical resolution increased to 60 levels to be consistent with the operational Eta. The Eta members were upgraded to use the (pre-March 2004) 12 km North American Eta version of the model physics and dynamics packages. RSM members received improved physics and computational schemes commensurate with the current Global Forecast System (GFS) model. SREF system physics diversity was increased (per NWS user request) by running several members using different cloud physics and convective parameterization schemes. The SREF scaled breeding technique was also improved by using the GFS ensemble technique. Details at http://wwwt.emc.ncep.noaa.gov/mmb/SREF-Docs/SREFJul04-NCO.pdf

August 24, 2004: A new global Coupled atmosphere-ocean Forecast System (CFS) was implemented at NCEP. CFS also replaced the current NCEP operational coupled seasonal forecast model (CMP14) used for Sea Surface Temperature (SST) prediction. CFS consists of a T62/64-layer version of the current NCEP atmospheric spectral Global Forecast System (GFS) model coupled to version 3 of the 40-level Global Fluid Dynamics Lab Modular Ocean Model (MOM3), and uses the NCEP Global

Ocean Data Assimilation (GODAS) for initialization. CFS' atmospheric and ocean components use direct coupling with no flux correction. The CFS runs at 0000 UTC each day to generate a 10 month forecast. The GODAS, which was implemented in September 2003, is also run daily to initialize the CFS. This new seasonal forecast system unifies the NCEP atmospheric models used for weather and seasonal forecasts.

During repetitive runs covering periods of 25 years (more than 3000 cumulative years of retrospective testing), it has shown more forecast skill for tropical Sea Surface Temperature than the current seasonal forecast model. Furthermore, in independent tests the new CFS has been shown to have SST forecast skill at least comparable to the most advanced statistical models out to at least 6 months.

September 1, 2004: The blending package in North Atlantic Hurricane (NAH) and North Pacific Hurricane (NPH) hurricane-generated wave models was upgraded to improve/correct blending of multiple simultaneous GFDL model runs with GFS winds.

September 9, 2004: The forecast range of hurricane-generated wave models (North Atlantic Hurricane [NAH] and North Pacific Hurricane [NPH]) was extended to 126 hours. This affects field outputs on the web only and point outputs on web and AWIPS.

September 17, 2004: NCEP implemented the Air Quality Forecast System (AQFS) at 1200 UTC. The new NCEP model will initially forecast ozone concentrations for the Northeast US, and runs twice daily (at 06 and 12 UTC) to provide forecasts of ozone out to 48 hours. The AQFS makes use of the 12 km Eta model to provide meteorological predictions that the Environmental Protection Agency CMAQ (Community Multi-scale Air Quality) model uses to produce ozone forecasts. The AQFS also performs 6 hour cycling and uses ozone predictions from NCEP's Global Forecast System for improved initial conditions. The CMAQ system includes chemical mechanisms to simulate various air quality constituents including tropospheric ozone, fine particles, toxics, acidic deposition, and visibility degradation. The implementation of AQFS is the first step in a decade-long NOAA-EPA program to create a National Air Quality Forecast System that will provide the US with forecasts of ozone, particulate matter and other pollutants, with enough accuracy and advance notice so action might be taken to prevent or reduce adverse effects.

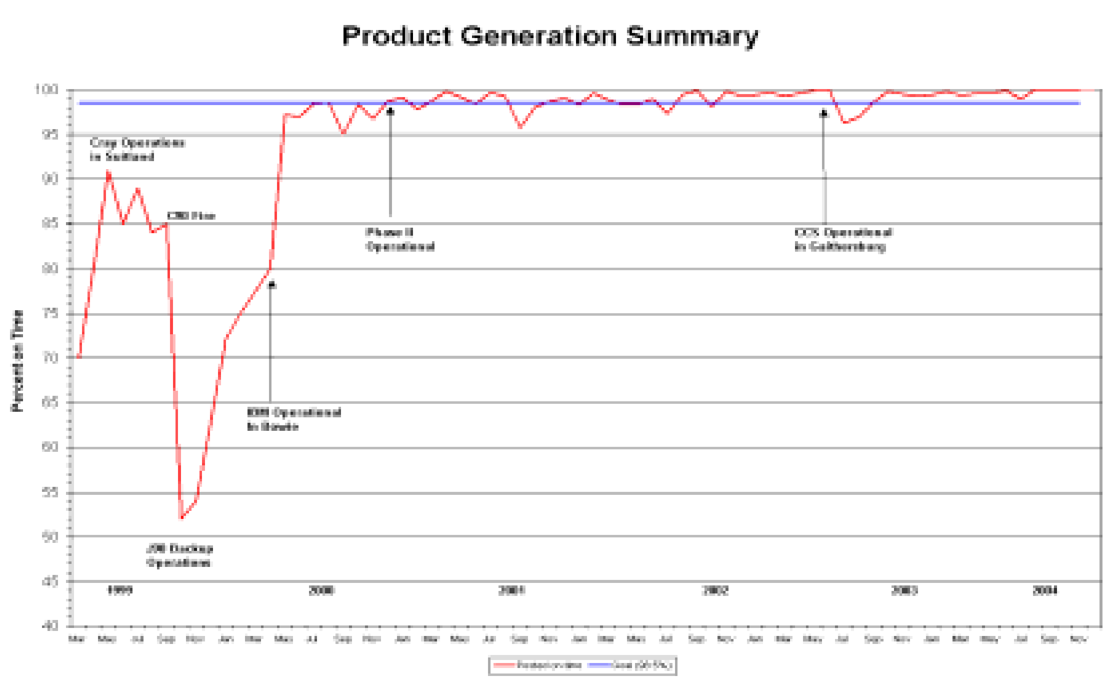
September 21, 2004: The first operational implementation of the Weather and Research Forecast (WRF) modeling system took place at 1200 UTC. The implementation consists of both the Non-hydrostatic Mesoscale Model (NMM) WRF core run with NCEP-supplied physics, and the Advanced Research (AR) WRF core (formerly known as the Eulerian Mass core) run with NCAR-supplied physics. Both versions of WRF receive initial conditions and lateral boundary conditions interpolated from the 12-km operational Eta model using the WRF Standard Initialization software developed by NOAA/OAR/FSL. The WRF version of the NMM has been upgraded with these changes to the model dynamic core: 1) the Matsuno vertical advection scheme has been replaced with the neutral, unconditionally stable Crank-Nicholson scheme, 2) the Smagorinsky constant in the lateral diffusion is reduced by 70%, 3) the effect of horizontal shear of vertical velocity has been added to the lateral diffusion scheme, and 4) the fundamental time step has been reduced by 10%. http://wwwt.emc.ncep.noaa.gov/mmb/mmbpll/wrftest/WRF-HRW-Readiness-Rev-13Sep04_files/v3_document.htm

September 28, 2004: The 20-km RUC analysis was changed to allow boundary-layer depth to be used to more effectively assimilate surface/METAR observations. This is a revised version of this PBL-based assimilation that was originally part of the April 2004 RUC change package. This new version

provides more coherent moisture fields aloft, and temperature and dewpoint analyzes near the surface.
http://ruc.fsl.noaa.gov/ppt_pres/NCEP-RUC-Sept04-change-e.htm

1.4 Operational Performance of the Production Forecast Suites

On-time production of numerical forecast products continued to improve during 2004 The average on-time production on the CCS increased to 99.60% in 2004 as compared to 99.00% in 2003. November 2004 recorded a record monthly average of 99.9975%. Reliability of receipt of products at the NWS Telecommunication Gateway was greatly improved in 2004, increasing to an average 99.28% from 98.5%. There were no major disruptions in product delivery during 2004, with no monthly average below 99.2%.



2. Equipment

2.1 IBM Regatta Cluster

The second phase of the system was installed in the IBM Gaithersburg, Maryland computer facility in August 2004 and in the NASA IV&V facility in Fairmont, West Virginia in September 2004. The two systems are functionally identical and can serve as either the Primary or Backup System. Each is comprised of IBM eServer Cluster 1600 pSeries 655 servers using the 1.7 GHz Power4+ CPU and IBM's High Performance Switch fabric. Each Cluster contains a total of 1408 processors and approximately 22 TB of disk space. The two clusters are connected by a dedicated, secure, high speed wide area network. The current configuration of the IBM CCS is contained in Table 1.

A back-end Hierarchical Storage Management System utilizing three Storage Tek Silos with a tape archive capacity of about 3 Pbytes is also usable by the entire system.

Table 1. IBM Systems

Processors	2816 1.7 GHz Power4+
Memory	5632 GB
Operating Systems	AIX
Disk Storage	44 TB disk subsystem

2.2 Additional Components

An SGI Origin 2000/32 and an Origin 3000/32 have been used to support non-operational projects during the last several years. A second Origin 2000 was dedicated to the ocean data assimilation project and the ocean-atmosphere coupled model. The Origin 3000 was retired in October 2004; the Origin 2000's are scheduled for removal in March 2005.

2.3 Communications

Figure 2 shows the communications network used by NCEP to exchange information within the NWS and to provide analysis and forecast products to users via the Internet. NCEP sends and receives data from the IBM facility in Gaithersburg, Maryland and Fairmont, West Virginia via multiple high speed OC3 (155 Mbits/sec) circuits. Communications between the World Weather Building (WWB) and the Telecommunications Gateway computer system at the Silver Spring Metro Center (SSMC) in Silver Spring, Maryland were upgraded from OC3 circuits to 1 Gigabit circuits. The WWB site is connected to three remote NCEP centers, the Storm Prediction Center (SPC) in Norman, Oklahoma, the Aviation Weather Center (AWC) in Kansas City, Missouri, and the Tropical Prediction Center (TPC) in Miami,Florida by a T3 line (45 Mbits/sec) through an ATM cloud to three T3 circuits, each with a capacity of 12 Mbits/sec. A direct circuit 1Gigabit circuit provides WWB Internet access to SSMC. From there, information is sent to the Internet over commercial ISP OC-12 lines to an Internet Service Provider (ISP).

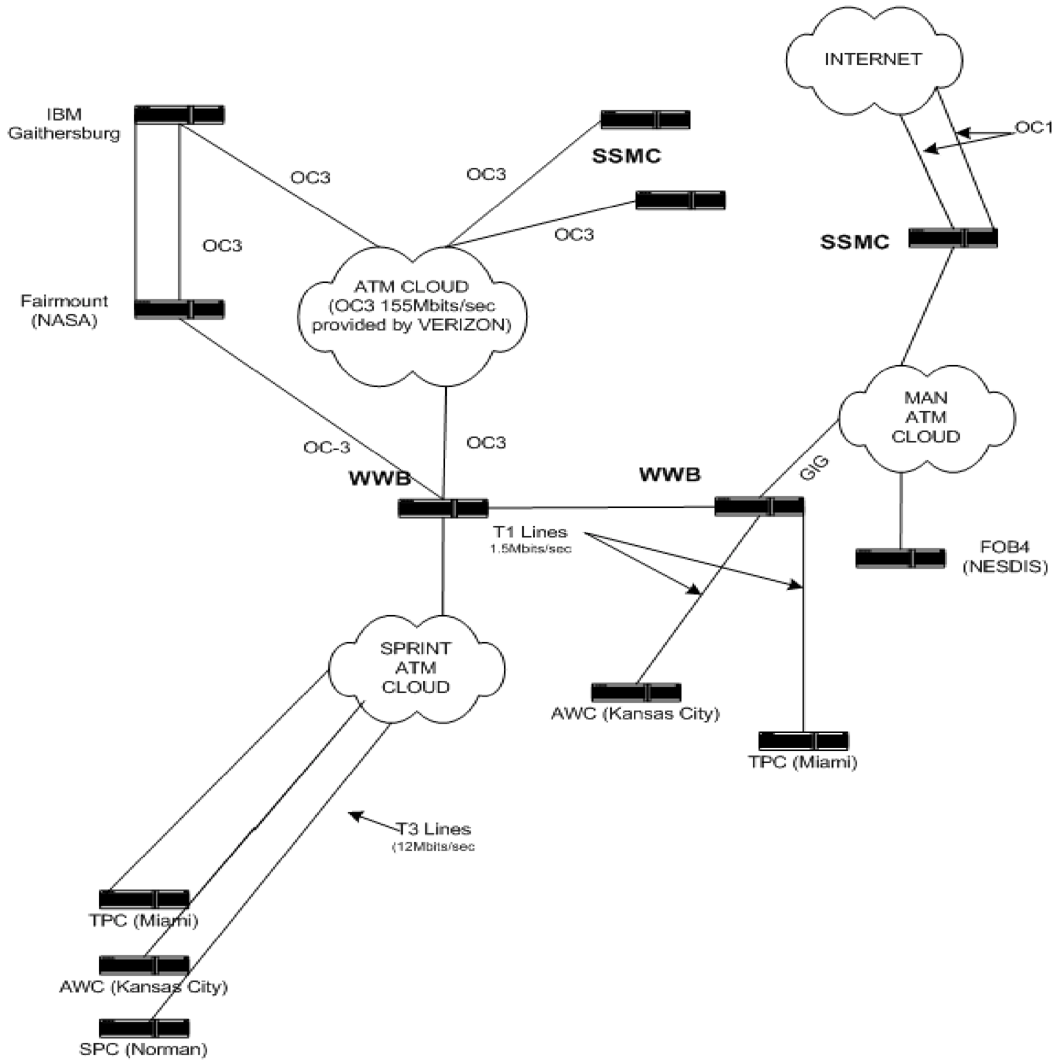


Figure 2. NCEP Network Configuration - 2004

3. Observational Data Ingest and Access System

3.1 Status at the End of 2004

3.1.1 Observational Data-Ingest

All observations for assimilation are stored in accumulating data files according to the type of data. Atmospheric observational data in 24 hour "tank" files remain on-line for up to 10 days before migration to offline cartridges. Certain marine observational data in 24 hour "tank" files remain on-line for up to 31 days before migration to offline cartridges. Observational data in 1 month "tank" files (consisting of some oceanographic data) remain on-line for up to 6 months before migration. While online, there is open access to them for accumulating late arriving observations and for research and study.

Changes to Data Ingest in 2004:

February 17, 2004: A CRISIS change was implemented in order to correct a coding error which caused a balloon drift calculation to be performed on some dropwindsondes (balloon drift should only be calculated for rawinsondes).

March 2, 2004: The early RUC2A run for the 00 and 12Z cycles, which performed only an analysis, was moved into the late RUC2B 00 and 12Z slot and the RUC2B run, which performed both an analysis and a forecast, was eliminated. The RUC2A will now perform both an analysis and a forecast for every cycle, initiating at 26-minutes past the hour for the 01-11 and 13-23Z cycles (as before) and now at 58-minutes past the hour for the 00 and 12Z cycles.

March 2, 2004: A package was implemented to allow Meteorological Data Collection and Reporting System (MDCRS) ACARS aircraft data received from ARINC via AFWA to provide a backup if the MDCRS ACARS data received directly from ARINC goes down. If more MDCRS ACARS reports are received from AFWA than are received directly from ARINC, all NCEP assimilation systems will use the AFWA reports. This should happen only rarely.

March 2, 2004: The NEXRAD Level 3 radial wind superob ingest was updated to properly process BUFR subsets with more than 800 report levels. Prior to this, only the first 800 report levels were processed. These data are assimilated by the EDAS.

March 18, 2004: A CRISIS change was implemented to correct a coding error which caused an incorrect calculation of sun angle, and in turn the temperature and height corrections, in the radiosonde intersonde bias (radiation correction) step prior to all NCEP analyses.

April 13, 2004: A package of changes was implemented in order to introduce several new data types to the dump processing. These include RASS virtual temperature profiles in the Eta, GFS and RUC networks; Cooperative Agency Profiler winds (including NOAA Boundary Layer Profilers) in the Eta, GFS and RUC; Japanese MET Agency profiler winds in the GFS; five new Mesonet types (including the Oklahoma MesoNet) in the Eta, RUC and RSAS; European AMDAR (E-ADAS) aircraft in the Eta and GFS; AIRS IR and AMSU-A 1B brightness temperatures in the GFS; and mobile synoptic land reports in the GFS. These are not yet assimilated by any operational NCEP analyses but are available for model data impact tests.

April 22, 2004: A CRISIS change was implemented to stop calculating virtual temperature on pressure levels above the tropopause because of inherent inaccuracies in the reported dewpoint depression values obtained from the rawinsonde moisture sensor at high levels.

June 15, 2004: A new Marine Ocean Data handling System (MODS) was implemented to provide a 31-day late-cutoff marine-relevant BUFR data base for the NCEP marine forecast systems. This initial implementation does not yet tie in with any operational systems.

June 29, 2004: The tropical cyclone position and intensity bulletin quality control code was changed after the discovery that all JTWC text records since July 2000 had a blank character incorrectly placed in the units digit for the radius of the last closed isobar. This caused the value to be low by a factor of ten, meaning that it was always replaced by a climatological value. Although FNMOC actually fixed the error in May 2004, this change allows historical runs to avoid this error and will keep this problem from recurring.

September 28, 2004: A package was implemented to allow NEXRAD Level 2.5 radial wind on-site superobs to be introduced into the NCEP BUFR database. These data have more tilt angles and are at higher precision than the Level 3 superobs still operational in the Eta 3DVAR assimilation. Also, the

Level 2.5 data is not thinned near the radar sites. These data have been tested in the EDAS and show a positive impact over the Level 3 data. The Level 2.5 radial wind superobs will be implemented into operations in early 2005 as part of the final Eta bundle.

September 28, 2004: The ASOS report dump duplicate-checking code was changed to always choose a "METAR" report over a duplicate "SPECI" (special) report in cases where neither are corrected, regardless of the receipt time (not randomly as before). This change was made because the "selected cities" processing, which uses this code, will not use the max/min temperature from a "SPECI" ASOS report.

September 28, 2004: A switch was made from NESDIS' non-Gaussian to its Gaussian form for GOES clear-sky brightness temperatures (imager radiances) that are ingested into the NCEP BUFR database. The Gaussian form is an improvement over the previous form and it contains additional quality information. These data are not operational in any NCEP analyses but are being tested in the GFS SSI.

September 28, 2004: Aqua and Terra MODIS satellite-derived IR and water vapor winds were introduced to the NCEP BUFR database, and are being included in the satellite-wind data dump processing in the GFS. These data are not operational in any NCEP analyses but are being tested in the GFS SSI.

September 28, 2004: GOES (low-level) picture triplet satellite winds stopped being ingested into the NCEP BUFR database or assimilated by any NCEP analysis. Their impact on NCEP analyses was negligible due to their small quantity compared to the low-level IR and water vapor winds from GOES.

September 28, 2004: Four new Mesonet types (West Texas, Wisconsin DOT, Louisiana State and Jackson State Universities, Colorado East Interstate 740) were added to the Mesonet data being dumped in the Eta, RUC and RSAS networks. The Mesonet data dumps are not yet assimilated by any operational NCEP analysis but are available for model data impact tests.

November 11, 2004: AWS Convergence Technologies, Inc. data was added to the Mesonet data dumps in the Eta, RUC and RSAS networks. This is a very large network covering schools and other sites across the U.S. The Mesonet data are not yet assimilated by any operational NCEP analysis but are available for model data impact tests.

4. Quality Control System

4.1.1 Interactive Phase

During the first phase, interactive quality control is accomplished by the Ocean Prediction Center (OPC) and the NCO/Senior Duty Meteorologists (SDMs). The OPC personnel use a graphical interactive system called CREWSS (Collect, Review, and Edit Weather data from the Sea Surface) which provides an evaluation of the quality of the marine surface data provided by ships, buoys (drifting and moored), Coastal Marine Automated Network (CMAN) stations, and tide gauge stations based on comparisons with the model first guess, buddy checks vs. neighboring platforms, the platform's track, and a one week history for each platform. The OPC personnel can flag the data as to the quality or correct obvious errors in the data, such as incorrect hemisphere, misplaced decimal, etc. The quality flags and corrections are then uploaded to the IBM CCS and are stored there in an ASCII file for use during the data retrieval process. The SDM performs a similar process of quality assessment for upper-air profile (rawinsonde, PIBAL, dropwindsonde) temperature, wind and moisture data; single-level aircraft [AIREP, PIREP, AMDAR (Aircraft Report, Pilot Report, Aircraft Meteorological Data Relay) , Meteorological Data Collection and Reporting System (MDCRS), reconnaissance temperature, wind and moisture data; satellite-derived wind data; and surface land and marine pressure, temperature, moisture and wind data. In certain situations, the SDMs use an interactive program which initiates the offline execution of two of the quality control programs (described in the next paragraph) and then review the programs' decisions before making assessment decisions. The SDMs use satellite pictures, meteorological graphics, continuity of data, and input comparisons (buddy checks) to decide whether or not to override automatic data QC flags.

During the past several years, the procedure described above was used daily to screen data that were suspected of containing errors. While CREWSS continues to be used daily, since the Fall of 2003, interactive quality control by the SDM's is only applied selectively in cases where there are indications of egregious errors.

4.1.2 Automated Phase

Separate automated quality control algorithms for rawinsonde, non-automated (AIREP and PIREP) and automated AMDAR aircraft, automated MDCRS ACARS aircraft, wind profiler, and NEXRAD Vertical Azimuth Display (VAD) reports are also executed. The purpose of these algorithms is to eliminate or correct erroneous observations which arise for various reasons including location, transcription or communications errors. Attempts are made, when appropriate, to correct commonly occurring types of errors. Rawinsonde temperature and height data pass through a complex quality control process using extensive hydrostatic, baseline, and horizontal and vertical consistency checks based upon differences from the 6-hour forecast. Corrections and quality marks are applied to the rawinsonde data. A complex quality control algorithm performs the quality control for all levels as a whole, rather than considering the mandatory levels first, and then the significant levels. In addition, an improvement was made to the way in which the hydrostratic residuals are calculated and used. AIREP, PIREP, and AMDAR aircraft reports are also quality controlled through a track-checking procedure by an aircraft quality control program. In addition, AIREP and PIREP reports are quality controlled in two ways: isolated reports are compared to the first guess and groups of reports in close geographical proximity are inter-compared. Both of the above quality control programs are run offline by the SDM as well as in automated QC codes. MDCRS ACARS data receive automated QC that flags a number of common errors in this data type, such as calm winds, spurious reports at 0.0 degrees East or North, and spurious reports above 100 hPa. Wind profiler reports are quality controlled with a complex quality control program using multiple checks based on differences from 6-hour forecasts, including increment, vertical statistical, temporal statistical, and combined vertical-temporal consistency checks. Finally, VAD wind reports are quality controlled with a similar type of program which also includes an algorithm to account for contamination by bird migration.

The final part of the quality control process in the Global Forecast System (GFS) production suite is for all data types to be checked using an optimum interpolation based quality control algorithm, which uses the results of both phases of the quality control. As with the complex quality control procedures, this program operates in a parallel rather than a serial mode. That is, a number of independent checks (horizontal, vertical, geostrophic) are performed using all admitted observations. Each observation is subjected to the optimum interpolation formalism using all observations except itself in each check. A final quality decision (keep, toss, or reduced confidence weight) is made based on the results from all individual check and any manual quality marks attached to the data. Results from all the checks are kept in an annotated observational database.

In the ETA/EDAS production suites, the 3DVAR analysis performs a comprehensive multi-platform quality control of the observations and generates statistical and graphical output of the results.

5. Monitoring System

5.1 Status at the End of 2004

5.1.1 Monthly Data Counts

During the first week of each month the average daily data counts for the previous month are tabulated and displayed on a web site, www.ncep.noaa.gov/NCO/DMQAB/counts. The data counts represent the number of individual geographical and temporal data receipts. Multiple data for each receipt, such as multiple level RAOB reports or multiple satellite channels, are not included. The statistics are divided into two classes, satellite data and non-satellite data. The counts in each class are further divided into categories based on general data type and subcategories according to specific observing platforms. Average daily data input counts for December 2004 are shown in Tables 2 and 3. The

"Percent Input" listed in the righthand column represents the percentage contribution of each category to the total data count.

Table 2. Average Daily Non-Satellite Data Counts for December 2003 for the Global Data Assimilation System

Category	Subcategory	Total Input	Percent Input
Land Surface	Synoptic	60920	
	METAR	128859	
	subtotal	189779	1.522
Marine Surface	Ship	2685	
	Drifting Buoy	12916	
	Moored Buoy	4844	
	CMAN	1967	
	Tide Gauge	3177	
	subtotal	25589	0.205
Land Soundings	Fixed RAOB	1378	
	Ship RAOB	23	
	Dropsonde	1	
	Pibal	261	
	Profiler	937	
	VAD Winds	6183	
	subtotal	8783	0.075
Aircraft	AIREP	3595	
	PIREP	985	
	AMDAR	28172	
	ACARS	87371	
	RECCO	4	
	subtotal	120127	0.964
Total	Non-Satellite	344278	2.762

Table 3. Average Daily Satellite Data Counts for December 2004 for the Global Data

Assimilation System

Category	Subcategory	Total Input	Percent Input
Satellite Soundings	GOES Soundings	76106	
	Ozone	3279	
	subtotal	79385	0.637
Satellite Winds	US IR Imagery	52211	
	Japan (IR and WV)	2145	
	Europe	76847	
	subtotal	131203	1.052
DMSP	SSMI Rainfall Rates	128786	
	SSMI Neural Net	128784	
	subtotal	257570	2.066
Satellite Surface	Quikscat Scatterometer Winds	157429	
	NASA TRMM Data	42828	
	subtotal	200257	1.606
ATOVS	HIRS2 1B	447142	
	HIRS3 1B	2000859	
	MSU 1B	23814	
	AMSUA 1B	587029	
	AMSUB 1B	8183054	
	GOES Radiances	211508	
	subtotal	11453406	91.876
	Satellite	12121821	97.238

6. Forecasting System

6.1 Global Forecast System

6.1.1 Status of the Global Forecasting System at the End of 2004

Global Forecast System Configuration: The global forecasting system consists of:

a) The final (FNL) Global Data Assimilation System (GDAS), an assimilation cycle with 6-hourly updates and late data cut-off times. NOAA-16 HIRS/3 observations were turned off in the Global Data Assimilation System (GDAS) in May.

b) The Global Forecast System (GFS) initializes the 384-hour forecasts run at 0000, 0600, 1200 and 1800 UTC with a data cut-off of 2 hours and 45 minutes using the 6-hour forecast from the FNL as the first guess. The resolution of the model for the first 84 hours is T254L64, T170L42 from 84 to 180 hours, and T126L28 from 180 to 384 hours. The Global Forecast System (GFS) model was upgraded in February to include sub-gridscale mountain blocking, which is the parameterization of the separation of airflow in the vertical with passage over mountainous terrain. The Global Forecast System mountain blocking parameterization improves the treatment of gravity wave momentum changes around sub-gridscale mountains. The scheme enhances friction to force lower-level parcels to flow around a mountain and lets upper-level parcels flow over the mountain.

c) Ensembles of global 16-day forecasts from perturbed FNL initial conditions (ten forecasts from 1200 UTC, and ten forecasts from 0000 UTC). Ensembles are run at T126 for the first 84 hours and at T62 after that. In March, the ensemble was upgraded to extend the forecast run at T126 spectral resolution from 84 out to 180 hours (improves ensemble support for 4-7 day forecasting, allows tropical cyclone tracking out to 7 days, and provides boundary conditions for the Short Range Ensemble Forecast out to 90 hours); to add 06Z and 18Z forecast runs for 4 daily cycles (matches the 4 GFS control forecasts, and provides more ensemble members for medium-range and week-2 forecasts); and to shorten the T126-resolution forecast time step from 20 to 10 minutes (improves the ensemble forecast quality by matching the GFS control time step).

Global Data Assimilation System: Global data assimilation for the FNL and GFS is done by a multi-variate Spectral Statistical Interpolation (SSI) analysis scheme using a 3-dimensional variational technique which incorporates a linear balance constraint, eliminating the need for a separate initialization step. The analyzed variables are the associated Legendre spectral coefficients of temperature, vorticity, divergence, water vapor mixing ratio, and the natural logarithm of surface pressure (ln psfc). All global analyses are done on 64 sigma levels at a T254 spectral truncation. Data cut-off times are 0600, 1200, 2100 and 0000 UTC for the 0000, 0600, 1200, and 1800 UTC FNL analyses, respectively, and 0245, 0845, 1445, and 2045 UTC for the 0000, 0600, 1200, and 1800 UTC GFS analyses.

Global Forecast Model: The global forecast model has the associated Legendre coefficients of the natural logarithm of surface pressure, temperature, vorticity, divergence, water vapor mixing ratio and cloud water/ice as its prognostic variables. The vertical domain ranges from the surface to 0.266 mb and is discretized with 64 sigma layers. The associated Legendre spectral coefficients for all variables are trucated (triangular) at T254L64 for the FNL. A semi-implicit time integration is used. The model includes a full set of parameterizations for physical processes, including moist convection, cloud-radiation interactions, stability dependent vertical diffusion, evaporation of falling rain, similarity theory, derived boundary layer processes, land surface vegetation effects, surface hydrology, and horizontal diffusion.

Global Forecast System Products: Products from the global system include:

a) Gridded (in GRIB format) Sea level pressure (SLP) and height (H), temperature (T), zonal wind component (U), meridional wind component (V), and relative humidity (R) at a number of constant pressure levels every 3 hours for the first 180 hours of all four runs of the GFS and every 6 hours from 180 hours to 384 hours;

b) Specialized aviation grids (in GRIB format) with tropopause H, T, and pressure as well as fields depicting the altitude and intensity of maximum winds and precipitation;

c) A large number of graphics products.

6.1.2 Future Plans for the Global Forecasting System

Changes planned for the production suite include:

a) Upgrade GDAS and GFS to use hybrid sigma-pressure vertical coordinates;

b) Upgrade GDAS to include a new SST analysis, surface emissivity model, sea ice model, AIRS data and MODIS winds, and a newer version of Noah LSM;

c) Increase GFS spectral resolution to T382/L64 (35 km) for 0-84 hrs of the forecast run, T254/L64 for 84-192 hrs, and T126/L64 for 192-384 hrs;

d) Upgrade global ensemble to include ETKF rescaling, a possible resolution increase and/or a membership increase;

e) Develop routine extratropical 6-10 day storm track products using GFS and ensemble output;

f) Implement an operational product for ensemble hurricane tracks;

g) Continue to develop the North American Ensemble Forecast System (GFS and Canadian Ensemble System) comprised of ensemble mean and spread for all variables, PQPF and a 6-hour PQPF for different precipitation.

6.2 Regional Forecast System

6.2.1 Status of the Regional Forecasting Systems at the End of 2004
Regional Forecast System Configuration:

The Regional Systems are:

a) The Mesoscale Eta Forecast Model (Meso Eta) provides high resolution (12 km and 60 levels) forecasts over North America out to 84 hours at 0000, 0600, 1200 and 1800 UTC. This modeling system and its data assimilation component (see below) was updated in March 2004. This bundle consisted of improvements to data assimilation (add use of GOES cloud top pressure and use of daily gage data for bias adjustment in the assimilation of precipitation) and changes to the Eta Land-surface model to use the precipitation type predicted by the model microphysics. In April, the extension part of the run, which had been performing the 60 to 84 hr forecast on a smaller portion of the computer, was included in the first piece. That first piece was allocated more computer resource so that more work was accomplished in the same time period (75 minutes) thus resulting in a speedup in the delivery of all forecasts, especially those in the 60-84 hr range. A briefing that describes the March changes in detail can be found at: http://wwwt.emc.ncep.noaa.gov/mmb/briefings/EtaWinter2004.briefing.html;

b) The Rapid Update Cycle (RUC) System, which generates (20 km and 50 level) analyses and 3-hour forecasts for the contiguous United States every hour with forecasts extended to 12-hr at 0000, 0300, 0600, 0900, 1200, 1500, 1800, and 2100 UTC. On 14 April 2004 a package of model and analysis changes was implemented. The model changes include modifications to the vertical advection of moisture, definition of coastline land-use, and treatment of microphysics. These changes improved the amount and areal coverage of precipitation, and the evolution of soil moisture. The analysis change, to use PBL depth to aid the assimilation of METAR data, was pulled later on 26 April 2004 but reinstated (after reformulation) in late September. This new version provides more coherent moisture fields aloft, and temperature and dewpoint analyzes near the surface;

c) The Nested Grid Model (NGM), whose North American grid has approximately 90 km resolution on 16 layers, and which generates 48-hr forecasts for North America twice daily at 0000 and 1200 UTC is used for MOS;

d) A 15 member Short Range Ensemble Forecast (SREF) system runs twice daily at 0900 and 2100 UTC with the forecast period extending out to 63 hours. There are 10 Meso Eta Model members (5 with Betts-Miller-Janjic convection and 5 with Kain-Fritsch convection) and 5 Regional Spectral Model members. All runs are made at 48 km and use the same North American continental domain as the Meso Eta. They are initialized from their own "breeding" cycles to make two pairs of positive and negative perturbations of the initial conditions. Lateral boundary conditions come from the medium range ensemble forecasts made from 0600 and 1800 UTC. The 48-km SREF (10 Eta /5 RSM members) was replaced in August with a 15-member Eta/RSM system at 32 km resolution with physics diversity.

e)

Model	**Convective Parameterization**	**Microphyiscs**	**Lateral Boundary Perturbation**
Eta	Betts-Miller-Janjic	Ops Eta (Ferrier)	control
Eta	Kain-Fritsch	Ops Eta (Ferrier)	control
Eta	Betts-Miller-Janjic	Ops Eta (Ferrier)	negative
Eta	Betts-Miller-Janjic	Ops Eta (Ferrier)	positive
Eta	Kain-Fritsch	Ops Eta (Ferrier)	negative
Eta	Kain-Fritsch	Ops Eta (Ferrier)	positive
Eta	Betts-Miller-Janjic with saturated vapor pressure profiles	experimental Ferrier	negative
Eta	Betts-Miller-Janjic with saturated vapor pressure profiles	experimental Ferrier	positive
Eta	Kain-Fritsch with full cloud detrainment	experimental Ferrrier	negative
Eta	Kain-Fritsch with full cloud detrainment	experimental Ferrrier	positive
RSM	Simplified Arakawa-Schubert	Ops GFS (Zhou)	control

Model	Convective Parameterization	Microphyiscs	Lateral Boundary Perturbation
RSM	Simplified Arakawa-Schubert	Ops GFS (Zhou)	negative
RSM	Simplified Arakawa-Schubert	Ops GFS (Zhou)	positive
RSM	Relaxed Arakawa-Schubert	Ops GFS (Zhou)	negative
RSM	Relaxed Arakawa-Schubert	Ops GFS (Zhou)	positive

The new SREF has much more spread among its members than the original system;

d) A set of High Resolution Window (HiRes) nested runs of the Nonhydrostatic Meso Model (NMM) are made following the completion of the GFS run suite whenever there is no GFDL hurricane model run. These runs get hourly boundary conditions and their initial conditions from the parent continental domain Meso Eta runs (see above). The HiRes version of the NMM uses 60 levels in the vertical, and runs to 48 hours. The single run of NCEP Non-hydrostatic Meso Model (NMM) in the HiResWindow suite was replaced in September with two runs - the WRF version of the NMM (WRF-NMM), and the WRF version of the Eulerian Mass core (WRF-EM) with physics chosen by NCAR.

WRF-NMM	Physics module	WRF-EM
Betts-Miller-Janjic	Convection	Kain-Fritsch
Ferrier	Microphysics	Ferrier
Mellor-Yamada-Janjic (Eta)	PBL	MRF scheme
Monin-Obukhov (Janjic Eta) scheme	Surface layer	Monin-Obukhov
OSU land-surface	Land-surface	OSU land-surface
GFDL (Eta)	Radiation	Dudhia

The WRF version of NMM was upgraded with changes to the model dynamic core: 1) the Matsuno vertical advection scheme has been replaced with the neutral, unconditionally stable Crank-Nicholson scheme; 2) the Smagorinsky constant in the lateral diffusion is reduced by 70%; 3) the effect of horizontal shear of vertical velocity has been added to the lateral diffusion scheme; and 4) the fundamental time step has been reduced by 10%. The NCEP physics for the WRF-NMM have these changes: 1) refined the input data on surface conditions (soil and vegetation type), 2) increased soil heat capacity which results in larger ground fluxes, 3) removed the dependence of roughness length (z0) on the height of topography, significantly reducing z0 over elevated terrain, 4) added the countergradient heat flux to the turbulent kinetic energy (TKE) equation and in the vertical heat diffusion, 5) increased the diagnostic mixing length, 6) reduced significantly the floor values for TKE and mixing length, 7) introduced increased residual turbulent mixing in the case of strong stability between the top of the surface layer and the layer above the inversion, 8) incorporated the effect of entrainment into the procedure for finding convective cloud top pressure, and 9) reduced the entropy change threshold for triggering deep convection. At 0000 UTC, a large 10 km nest is run for Alaska and a small 8 km domain is run for Hawaii. The WRF Alaskan nested domain was reduced and changed to match the CONUS run resolution. At 0600 UTC a large 8 km nest is run for the western portion of the CONUS and a small 8 km nest is run for Puerto Rico. At 1200 UTC, a large 8 km nest is run for the central portion of the CONUS and a small 8 km domain is run for Hawaii. At 1800 UTC a large 8 km nest is run for the eastern portion of the CONUS and a small 8 km domain is run for Puerto Rico;

f) Fire Weather / Incident METeorologist (IMET) Support runs of an 8 km 60 level non-WRF NMM are run four times per day over the top of the Meso Eta with only a slight time-lag. The Fire Weather control facility in Boise Idaho and NCEP's Storm Prediction Center decide which of 26 selectable 8 km domains are to be run and notify the Senior Duty Meteorologist (SDM), who inputs the information directly into the production system. The Fire Weather run uses a non-WRF version of the NMM and receives hourly boundary conditions (out to 48 hours) and initial conditions from the parent Meso Eta run. Gridded guidance is shipped to the TOC where regional centers pick it up and prepare fields for transmission to IMETs, who have been dispatched to wild fire locations and can display the guidance on laptops equipped with satellite communications and FX-NET software (to emulate AWIPS). Fire Weather grids are 25% the size of the large CONUS HiRes nests. There are 21 overlapping grids covering the CONUS plus 5 grids covering Hawaii, Juneau, Fairbanks, Anchorage and Puerto Rico;

g) A new Air Quality Forecast System (AQFS) became operational on 17 September 2004. This was in response to a Congressional amendment to the Clean Air Act (CAA) to bolster America's efforts to attain the National Ambient Air Quality Standards (NAAQS). The AQFS has at its core the Community Multiscale Air Quality (CMAQ) model from the Environmental Protection Agency (EPA). CMAQ is driven by 12 km meteorological fields from the Meso Eta model forecasts and by detailed inventories of fixed and mobile emissions sources. The AQFS was implemented over the northeastern United States and produces 48 hour forecasts of surface ozone concentrations. This forecast guidance is sent in gridded form to EPA for distribution to official forecasters at the individual state level;

h) A new Downscaled GFS with Eta extension (DGEX) run was instituted in the 60-84 hr Meso Eta extension slot vacated in a) above. In its place, the Meso Eta 84 hr forecast is extended to 192 hours over a reduced (1/6 or less) domain. The DGEX runs are made at the same 12 km 60 level resolution as the Meso Eta and receive lateral boundary conditions from the previous GFS forecast. Since the domain has been reduced (to fit the run into the available runslot), the influence of the GFS boundaries is hastened and the desired downscaling of the GFS is accomplished. At 0000 UTC and 1200 UTC, DGEX is run on an Alaskan domain and at 0600 UTC and 1800 UTC, DGEX is run over the CONUS. This 12 km guidance (much finer than the ~50 km data available from the GFS) is used by NWS WFO's to initialize their extended range (3-8 day) grids for preparation of the National Digital Forecast Database products which are currently at 5 km resolution.

Regional Forecast System Data Assimilation: Initial conditions for the four Meso Eta forecasts are produced by a multivariate 3-dimensional variational (3DVAR) analysis which uses as its first guess a 3 hour Meso Eta forecast from the Eta-based Data Assimilation System (EDAS). The EDAS is a fully cycled, self-contained system using global fields only for lateral boundary conditions. Data cut-off is at 1 hour and 10 minutes past the nominal analysis times. In most cases, the data time window radius is 1.5 hours about the center of the data dump cycle time. No initialization is applied. Assimilation of observed precipitation (in the form of analyses of automatic gauge and radar estimates) is performed within the model component of the EDAS. In 2004, the EDAS model component was upgraded to assimilate GOES cloud top radiances in the Eta 3DVAR analysis and use daily gauge data for precipitation assimilation bias adjustment. The bias adjustment applied to assimilated precipitation

reduces the dry bias in the EDAS soil moisture, which was caused by the low bias in the assimilated multi-sensor (gauge+radar) precipitation analysis. Initial conditions for the RUC runs come from a multivariate 3DVAR analysis of state variables and a univariate cloud analysis.
After the RUC 3DVAR analysis, initialization is achieved using a digital filter which includes diabatic processes. Initial conditions for the NGM runs come from a combination of Meso Eta analysis over North America and 6-hr forecast from the GDAS over the rest of the Northern Hemisphere. After the Meso Eta analysis is interpolated to the NGM grid, an implicit normal mode initialization is performed.

Regional Forecast System Models: The Meso Eta Model has surface pressure, temperature, u, v, turbulent kinetic energy, water vapor mixing ratio and total condensate as its prognostic variables. The vertical domain is discretized with 60 eta layers with the top of the model currently set at 25 mb. The horizontal domain is a 12 km semi-staggered Arakawa E-grid covering all of North America. An Euler-backward time integration scheme is used. The model is based on precise dynamics and numerics, a step-mountain silhouette terrain representation and includes a full set of parameterizations for physical processes, including Janjic modified Betts-Miller convection, Mellor-Yamada turbulent exchange, Fels-Schwartzkopf radiation, a land surface scheme with 4 soil layers and predictive cloud scheme. The lateral boundary conditions are derived from the prior global model forecast at a 3 hour frequency.

The Nonhydrostatic Mesoscale Model (HiRes WRF-version and Fire Weather version) has surface pressure, temperature, horizontal velocities u and v, turbulent kinetic energy, specific humidity, total condensate, ratio of liquid to solid condensate, nonhydrostatic vertical velocity and nonhydrostatic pressure as its prognostic variables. The NMM uses a hybrid sigma-pressure vertical coordinate discretized to 60 layers where the lowest approximately 42 layers are terrain following topped by approximately 18 constant pressure surfaces above 420 mb with the top of the model set at 50 mb in the HiRes and at 25 mb in the Fire Weather runs. The horizontal grid uses an Arakawa E-grid and covers nests of various sizes within the North American domain of the Meso Eta. The model is based on precise dynamics and numerics, like the Meso Eta, but use of shape-preserving conservative schemes is more prevalent. The NMM uses a split explicit/implict approach to solving the equations: fast waves (inertia gravity) are solved using a forward-backward scheme; vertically propagating sound waves are solved implicitly; horizontal advection of T, u and v is handled using Adams-Bashforth; vertical advection of T, u and v uses an off-centered Crank-Nicholson; and advection of TKE and water species uses a flux-corrected forward scheme. The NMM includes a full set of parameterizations for physical processes similar to the Meso Eta, including Janjic modified Betts-Miller convection, Janjic modified Mellor-Yamada turbulent exchange, Ferrier gridscale cloud and precipitation, Fels-Schwartzkopf / Lacis-Hansen radiation and NCEP-Oregon State University-Air Force Weather Agency-Office of Hydrology Development (NOAH) land surface scheme with 4 soil layers. The lateral boundary conditions are derived from the current Meso Eta model forecast at a 1 hour frequency for Fire Weather and at 3 hour frequency for HiRes.

The WRF-Eulerian Mass-core (EM) Model was developed by NCAR (used for HiRes runs) has the mass in the column (hydrostatic surface pressure), potential temperature (hydrostatically coupled to pressure in the column), horizontal velocities u and v, the vertical velocity, the geopotential, water vapor, total condensate and ratio of liquid to solid condensate as its prognostic variables. The WRF-EM uses a sigma vertical coordinate based on hydrostatic pressure which is discretized to 50 layers with the top of the model currently set at 50 mb. The horizontal grid uses an Arakawa C-grid at 10 km for nests of various sizes within the North American domain of the Meso Eta. The WRF-EM Model uses a 3rd Order Runge-Kutta time integration scheme, uses typically 5th order finite differencing for horizontal advection and 3rd order for vertical advection. The WRF-EM includes a full set of parameterizations for physical processes chosen by NCAR including Kain-Fritsch convection, MRF boundary layer, Ferrier gridscale cloud and precipitation, Dudhia radiation and NOAH land surface scheme with 4 soil layers. The lateral boundary conditions are derived from the current Meso Eta model forecast at a 3 hour frequency for HiRes.

The RUC system was developed by the NOAA/Forecast Systems Laboratory. The RUC run provides high-frequency, short-term forecasts on a 20-km resolution domain covering the lower 48 United States and adjacent areas of Canada, Mexico, and ocean. Run with a data cut off of 26 minutes at 0100-1100 and 1300-2300 UTC and 58 minutes at 0000 and 1200 UTC, the analysis relies heavily on high temporal resolution asynoptic data from surface marine and METAR (and soon mesonet) reports, wind profiler, GOES satellite layer PW retrievals and derived wind data, and MDCRS ACARS aircraft data. In most cases, the data time window radius is 0.5 hours about the center data dump cycle time, but for some data types (i.e. satellite derived winds) it is extended further back in time. One of its unique aspects it is use of a hybrid vertical coordinate that is primarily isentropic. Most of its 50 levels are isentropic except for layers in the lowest 1-2 km of the atmosphere where terrain-following coordinates are used. The two types of surfaces change smoothly from one to another. A full package of physics is included with 5 cloud precipitation species carried as historic variables of the model.

The NGM model uses a flux formulation of the primitive equations, and has surface pressure, and sigma u, sigma v, and sigma q as prognostic variables where Θ is potential temperature and sigma q specific humidity. The finest of the nested grids has a resolution of 85 km at 45 N and covers North America and the surrounding oceans. The coarser hemispheric grid has resolution of 170 km. Fourth-order horizontal differencing and a Lax-Wendroff time integration scheme are used. Vertical discretization is done using 16 sigma levels. Parameterized physical processes include surface friction, grid-scale precipitation, dry and moist convection, and vertical diffusion.

Regional Forecast System Products: Products from the various regional systems include:

a) Heights, winds, temperature, winds aloft:
   (1) Meso Eta to 84 hr at 0000, 0600, 1200 and 1800 UTC every 25 hpa and every 3 hours;
   (2) RUC (to 3 hr or 12 hr) every 25 hpa and hourly; and
   (3) NGM (to 48 hr) every 50 hpa and every 6 hours;

b) 3, 6 and 12 hour accumulated precipitation (totals & convective);

c) Freezing level;

d) Relative humidity;

e) Tropopause information;

f) Many model fields in GRIB format;

g) Hourly soundings in BUFR at hundreds of sites (1400 for Meso Eta, 400 for RUC and NGM);

h) Hundreds of graphical output products and alphanumeric bulletins;

(1) DGEX grids include subset of above and are distributed via AWIPS Satellite Broadcast Network;
(2) HiResWindow and FireWx grids include subset of above and are downloaded from servers and viewable on INTERNET webpages.

Operational Techniques for Application of Regional Forecast System Products: Model Output Statistics (MOS) forecasts of an assortment of weather parameters such as probability of precipitation, maximum and minimum temperatures, indicators of possible severe convection, etc. are generated from NGM and Meso Eta model output. These forecasts are made using regression techniques based on statistics from many years of NGM forecasts and several seasons for the Meso Eta.

6.2.2 Future Plans for the Regional Forecast Systems

Year 2005 Goals

a) Extend current 2-model WRF HiResWindow to include its full with 6 member ensemble made from equal number of runs based on NCEP developed WRF-NMM and NCAR developed WRF-EM by adding a pair of runs for each made by breeding cycle approach;

b) Implement improvements to Air Quality Forecasting System (AQFS) and extend its domain coverage from just Northeast US domain to all of eastern US;

c) Upgrade Meso Eta Model, then freeze it until WRF-NMM replacement in Spring 2006 - final upgrades to include: upgrades to NOAH Land-Surface Model, refined treatments for gridscale cloud & precip, simplified assimilation of observed precipitation analyses and enhanced output capabilities;

d) Upgrade Meso Eta 3DVAR analysis, then freeze it until WRF-GSI replacement in Spring 2006 - final upgrades to include: assimilate Doppler radar Level II.5 radial velocities and assimilate surface temperature observations over land with new 2DVAR component using anisotropic covariance modeled to terrain (sfc temps were turned off September 2003);

e) Improve Regional Ensembles in both resolution (from 32 km to 26 km) and diversity of members (add 6 WRF-based members using two model configurations to existing 15 members based on just 6 model configurations), add bias correction, add product support for Alaska, add hourly BUFR output, improve ensemble products and their display & dissemination;

f) Upgrade RUC to higher resolution (13 km) and make physics and 3DVAR refinements;

g) Upgrade NMM in FireWx & Homeland Security runs to the WRF common modeling infrastructure version of WRF-NMM;

i) Begin assimilating surface mesonet data;

j) Begin assimilating GPS Integrated Precipitable Water (GPS-IPW) data;

k) Begin assimilating GOES-12 radiance data (Eta/EDAS);

l) Begin assimilating Cooperative Agency (CAP) wind profiler data (an addition to NOAA Profiler Netword data now assimilated).

6.3 Specialized forecasts

a) The Global Ocean Data Assimilation System (GODAS). The GODAS uses the Modular Ocean Model version 3 (MOM3) together with a 3-D VAR to produce the state of the ocean on a daily basis. The atmospheric fluxes from GDAS are used to provide the surface forcing. GODAS is used to initialize a global ocean-atmosphere coupled model that was implemented in 2004.

b) The East Coast-Regional Ocean Forecast System produces a nowcast and a 48-hour forecast once every day. The Princeton Ocean Model, forced by the surface fluxes from NCEP's operational Eta model, is used to produce the ocean forecasts. The ocean initial conditions for each forecast cycle are created by advancing the initial conditions of the previous forecast cycle to the current time by using the EDAS analysis fluxes and assimilation of in-situ and satellite derived SST's and sea surface height anomalies derived from altimeters.Graphic products and grid point numerical fields are made available to the user community over the internet at http://polar.ncep.noaa.gov.

c) NCEP is working on a common coupled ocean-atmosphere modeling framework that would make it possible to provide forecasts on regional, basin, and global scales, as needed, in a unified and efficient manner. This new effort is being undertaken using the Hybrid Coordinate Ocean Model (HYCOM) system, a collaborative effort involving several partners from academic, research, government, and private sectors. In NCEP's HYCOM system, regional and basin scale domains will be nested in the global domain as needed. All the models will be forced by fluxes from NCEP's GFS and will include a full suite of ocean data assimilation procedures, tidal forcing, and fresh water discharges into the coastal areas. The preliminary effort at this time focuses attention on the Atlantic Ocean Basin (25S to 75N) using a variable horizontal grid with a resolution of approximately 15 km in the eastern part of the basin and 4-5 km along the western part and the Gulf of Mexico. The model has 26 vertical hybrid coordinates. The model spin up using 6 hourly NCEP's GFS winds has been completed and model runs with real-time forcing and assimilation of satellite altimetry and SST's are about to begin. The system will be capable of supporting NOAA's National Ocean Service's development of higher resolution bay and estuarine forecast models as well as NCEP's development of improved coupled ocean atmosphere models for tropical hurricane prediction.

d) NCEP runs a daily real-time, global high-resolution, 1/2 Degree (latitude, longitude grid) SST analysis based on in-situ data and AVHRR satellite retrievals from NOAA 17. This analysis was developed in part to meet requirements for a high resolution SST analysis for the NCEP regional atmospheric forecast model (Eta model). This analysis is based on a 2 dimensional variational analysis method using recursive filtering. The SST product is distributed over the

GTS, and on the Branch web page. (http://polar.ncep.noaa.gov.) In 2004, development began of a new higher resolution SST analysis on a 1/12 degree global grid to improve the structure of SST for smaller scale ocean features (Gulf Stream, upwelling areas), coastal regions, and inland lakes. This analysis is designed to run in a multi-tasking computer environment to speed up processing time. This version of the analysis will be capable of including SST retrievals from multiple satellite systems. The analysis currently includes AVHRR data from NOAA 16 & 17, and will include data from GOES and AMSR-E SST retrievals after completion of studies on error assignments to data sets and background and correlation length scales.

e) Daily ocean wave forecasts are produced at NCEP on a global and a regional basis over areas for which the NWS is responsible to provide warnings and forecasts. All the global and regional forecasts are produced 4 times a day using the NOAA WaveWatch 3 (NWW3) model driven by the analysis and forecast winds from the NCEP's operational Global Forecast System. In FY 2004, the following changes were made to the wave model suite. Data assimilation of buoy and ERS2 altimeter data was incorporated in the global NWW3 wave model in March. No assimilation is performed in the regional models. The forecast range of all models was extended. For the hurricane wave models, the forecast range was extended to 126h in September. For all other models, the forecast range was extended to 180 hours in March. Finally, some fine tuning was performed on the hurricane wave model. The Garden Sprinkler Effect alleviation was improved by re-tuning the smoothing factors and by some other minor numerical adjustments on June 1. On September 1, some bug fixes were applied to assure the proper blending of multiple hurricanes into a single wind field (see http://polar.ncep.noaa.gov/waves for relevant details on models, products, validation, codes, etc).

f) The operational NWW3 model suite consists of a global model and three 'year-round' regional models covering the following domains: Gulf of Alaska and Bering Sea (AKW), Western North Atlantic (WNA) and Eastern North Pacific (ENP). During hurricane seasons, the NWW3 expands to include two other regional implementations: the North Atlantic and North Pacific hurricane models, NAH and NPH. All models forecast out to 7.5 days (hurricane wave models maintain their 3-day forecast limit). The global WaveWatch-III (WW3) model now assimilates buoy and ERS2 altimeter data. In 2005, NCEP will apply the experimental NOAA Wavewatch III (NWW3) to Great Lakes domains, test Eta forcing (0-84 hours), and include lake ice cover.

g) NCEP uses a separate atmospheric model developed by NOAA's Geophysical Fluid Dynamics Laboratory (GFDL) during hurricane seasons. NCEP runs the GFDL model with a system of two nested moving grids whenever the development of a tropical storm is detected in the northern hemisphere. Model runs are made for individual storms, producing detailed wind fields for up to four individual co-existing tropical cyclones. NWW3 hurricane wave models use the GFDL winds as input. NAH and NPH wave model grids are identical to the WNA and ENP GFDL model domains, respectively. The WNA and ENP models are run even if hurricanes are present, providing an 'early' forecast. The NAH and NPH model results are available later because they must wait for the completion of the GFDL runs. Even if no GFDL data is available, the NAH and NPH models are run throughout the hurricane season to assure that hurricane swells can be tracked for their entire life cycle in each model domain. In 2005, improved cloud microphysics and coupling to the Noah Land Model will be incorporated into the GFDL system.

h) Future directions for ocean models and analyses over the next 2 years:
-Add products reflecting user demand, such as wave steepness measures;
-Expand the wave field separation scheme to produce spatial fields of individual wave systems;
-Start producing wave ensemble forecasts;
-Couple the wave model to hurricane model to take effects of sea state on surface into account;
-Develop a NWW3 based wave forecast system for the Great Lakes;
-Start to evaluate Atlantic Basin HYCOM model performance and start implementation actions;
-Develop and test a dynamical storm surge forecast model using HYCOM Atlantic Basin model incorporating wave effects on water level and current forecasts.

i) Future directions for ocean models and analyses beyond the next 2 years:
-Couple the wave model to atmosphere and ocean models;
-Develop a multi-scale environment for WAVEWATCH III, with two-way information flow between different domains, and replace the present set of models with a single multi-scale model, using high resolution only where needed;
-Investigate alternative economical approximations of the well known exact interactions to improve the spectral shape;
-Develop and test global HYCOM model performance and nested regional domains for the West Coast, Gulf of Alaska, and the Hawaii region;
-Couple global HYCOM-GFS;
-Couple Regional HYCOM and hurricane prediction models.

j) A 1-tier coupled Climate Forecast System (CFS) was implemented in 2004. This system replaces earlier versions of the coupled forecast model (cmp14) and the tier-2 seasonal forecast model (SFM). A 23-year retrospective forecast with 15-member ensemble has been done to provide calibration for the real time forecast. The CFS is initialized by for the atmosphere by the NCEP Reanalysis-2 and by the Global Ocean Data Assimilation (GODAS) for the ocean. The same data assimilation systems are also used to initialize the retrospective forecasts. The atmospheric model of the CFS is the 2003 version of the NCEP GFS model. The resolution of the atmospheric model is T62L64. The ocean model is a version of the Modular Ocean Model (MOM3) with 40 levels in the vertical and 1-degree latitude/longitude in the horizontal. In the region 10S-10N, the latitudinal resolution is 1/3 degree. Currently the CFS is run once daily to 9 months. A set of the daily runs are intended to be used as an ensemble.

6.4 Verification of Forecast Products for Year 2004

Annual verification statistics are calculated for NCEP's global models by comparing the model forecasts to the verifying analysis and the model forecast interpolated to the position of verifying rawinsondes (see Tables 4 and 5). The parameter used in the verification is the inverse S1 score. The lower this score, the more accurate were the model predictions.

Table 4. Verification against the Global Analysis for 2004. Change from 2003 statistics in parentheses. Negative values (BLUE) indicate improvement; positive values (RED) indicate degradation.

Statistic	GFS 24 hr	GFS 72 hr	GFS 120 hr
500hPa Geopotential RMSE(m)			
Northern Hemisphere	12.0 (-0.3)	30.4 (-0.6)	55.3 (-0.8)
Southern Hemisphere	14.4 (+0.1)	37.2 (+0.2)	65.3 (+1.4)
250hPa Wind RMSVE(m/sec)			
Northern Hemisphere	4.7 (+0.1)	9.9 (+0.1)	15.0 (+0.1)
Southern Hemisphere	4.9 (+0.1)	10.4 (+0.1)	15.8 (+0.3)
Tropics	4.1 (0.0)	7.0 (+0.1)	8.6 (+0.1)
850hPa Wind RMSVE(m/s)			
Tropics	2.6 (-0.1)	4.0 (-0.1)	4.7 (-0.2)

Table 5. Verification against rawinsondes for 2004. Change from 2003 statistics in parentheses. Negative values (BLUE) indicate improvement; positive values (RED) indicate degradation.

Statistic	GFS 24 hr	GFS 72 hr	MRF 120 hr
500hPa Geopotential RMSE(m)			
North America	12.8 (0.0)	32.6 (+1.1)	55.6 (+0.8)
Europe	16.3 (+0.8)	33.3 (-0.4)	60.8 (+0.9)
Asia	14.8 (+0.1)	28.4 (+0.1)	46.2 (+0.8)
Australia/New Zealand	11.7 (-0.7)	21.6 (0.0)	36.4 (+0.3)
250hPa Wind RMSVE(m/s)			
North America	6.4 (0.0)	12.0 (+0.3)	17.2 (+0.3)
Europe	5.9 (0.0)	11.0 (-0.3)	17.3 (-0.2)

Asia	6.1 (-0.2)	10.3 (-0.3)	14.2 (+0.1)
Australia/New Zealand	6.2 (0.0)	9.6 (+0.1)	13.5 (+0.3)
Tropics	5.8 (+0.1)	7.6 (+0.1)	8.6 (0.0)
850hPa Wind RMSVE(m/s)			
Tropics	4.2 (-0.1)	5.0 (-0.2)	5.7 (-0.2)