Progress Report on the Global Data Processing System 2005

THE NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION
NATIONAL WEATHER SERVICE

U.S.A.

1. Highlights for Calendar Year 2005

The most significant event of 2005 from an operational standpoint was the initiation of operations on the new IBM Power-4 system, with full backup capabilities in a geographically separate region. This is the first time in NCEP's history that a backup system was available to run the full suite of numerical forecast products.

1.1 Major changes to the NCEP Production Suite

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

May 3, 2005: NCEP implemented a final upgrade package for the Eta Modeling system in the NAM (North American Model) run. This package included changes to the 3DVAR analysis, precipitation assimilation, Eta Model physics (including the Noah Land Surface Model (LSM)), and NAM output. The 3DVAR upgrade allows the improved use of on-time overland surface temperature observations by including an independent 2DVAR analysis of surface temperatures with anisotropic covariance tied to terrain. In addition, Level 2.5 88D radial velocity (on-site derived superobs) were added to the 3DVAR analysis. The on-site generation and central collection of these data are a result of one of the NWS' first Data Requirements Documents established in FY1999. Precipitation assimilation methods were streamlined in the NAM Data Assimilation System (NDAS) to make it more robust and forward-compatible with future modeling systems (Weather and Research Forecast (WRF) or Earth System Modeling Framework). The Noah LSM upgrade included new higher resolution vegetation/soil type databases and retuned vegetation parameters, which reduce the current summertime warm daytime bias and drying trend in precipitable water/low-level moisture and reduce wintertime surface temperature cold bias over snow pack under stable boundary layer conditions. The Eta model physics has a modified radiation scheme to "see" thicker clouds for better absorption and a modified cloud fraction formula to allow for more partial cloudiness. NAM output changes include an improved surface visibility computation that uses the convective precipitation rate, precipitation output for use by the LSM, and clear-sky radiation fluxes for use by the Air Quality Forecast System.

May 10, 2005: NCEP implemented an upgrade to the GFDL (Geophysical Fluid Dynamics Laboratory) Hurricane Model before the June 1st start of the Atlantic hurricane season. The upgraded GDFL model features an increase in the resolution of the movable inner grid, an improved specification of the initial storm vortex, and improved surface friction that is used to compute the low-level winds. The high resolution inner grid, which follows the storm center as it moves, has been upgraded to 9 km resolution. The improved storm vortex specification will more accurately depict the location and intensity of the storm circulation at the start of the model forecast. These improvements were tested against a six week period of the 2004 hurricane season and showed that the new GDFL model had a 15% improvement in storm track forecast accuracy over the old model. For the first time, the GDFL model also showed forecast skill over statistical models in predicting storm intensity 3 to 5 days in the future. The improved GDFL Hurricane Model bases its forecasts on initial conditions provided by an improved version of NCEP's Global Forecast System (GFS) model, which was also implemented this spring.

May 31, 2005: NCEP implemented an upgrade to the GFS (Global Forecast System) model. This upgrade included improvements to the GFS forecast model and analysis. The GFS forecast model increased its spectral resolution to T382 (~35 km) for the first 180 hours (7.5 days) of its forecast, and to T190 (~70 km) for the remainder of the 16 day forecast period. The new GFS also included reduced vertical diffusion and enhanced mountain blocking, a new sea ice model, and the latest Noah land surface model. The GFS analysis also increased its horizontal spectral resolution to T382 and began using temperature data derived from the Atmospheric Infrared Sounder (AIRS) and Advanced Microwave Sounding Unit (AMSU) instruments on the NASA Aqua satellite. The GFS now outputs new stratospheric products for the NCEP Service Centers and additional soil moisture outputs for external users. The new GFS will provide better forecasts (as measured by forecast skill) out to 16 days, and more accurate hurricane track and intensity forecasts when used with the improved 2005 GFDL hurricane model.

June 28, 2005: An improved version of the WRF (Weather and Research Forecast) HRW (High Resolution Window) domains, made up of the WRF Non-hydrostatic Mesoscale Model (WRF-NMM) core and the Advanced Research WRF (ARW) core, was implemented. The WRF-NMM internal resolution changed from 8 km/60 levels to 5.1 km/35 levels. The ARW changed its internal resolution from 10 km/50 levels to 5.8 km/35 levels. Both cores turned off convective parameterization calls and now use the Ferrier cloud/microphysics package. The HRW output resolution did not change. The new WRF HRW configuration produces better forecaster guidance on convective initiation and extra detail for critical local weather phenomena forecasts.

June 28, 2005: An improved version of the RUC model running at NCEP transitioned to operations at 1200 GMT. The new RUC increased its horizontal resolution from 20 km to 13 km, included the assimilation of new types of observations, changes to the model, hourly forecasts now extended out to 9 hours, and improved post-processing. New data types include Global Positioning System precipitable water, METAR clouds, and Mesonet temperature and dew point. Model changes include improvements related to cloud microphysics, convective parameterization, radiation-cloud effects, and frost formation. These model changes will improve the RUC's near-surface and precipitation forecasts, depiction of clouds/icing, and frontal/turbulence forecasts.

August 16, 2005: NCEP implemented an upgrade to the GFS (Global Forecast System) Ensemble at 1200 GMT. This upgrade extended the highest-resolution T126 (~105 km) forecast beyond its current 7.5 days out through the entire 16-day GFS forecast period, shortened the model perturbation breeding cycle from 24 hours to 6 hours, fixed a software bug in the model rescaling factors, and relocated tropical storm vortices in the initial model perturbations and tuned the perturbations. Extending the high horizontal model resolution will improve ensemble forecast accuracy for the 5-10 day forecast period and help with week-2 forecasts by increasing the ensemble spread and probabilistic forecast skill. Changing the perturbation breeding cycle will decrease uncertainty (measured by model spread) over the short term (1-3 day) forecasts and increase the model's skill for short lead-time forecasts. Relocating the initial model tropical storm vortex reduces forecast storm track error by 10% and model spread for short lead-time (1-3 day) forecasts, as was shown in tests rerunning the 2004 hurricane season.

August 31, 2005: NCEP implemented an upgrade to the AQFS (Air Quality Forecast System) at 1200 GMT. The domain covered by AQFS was expanded to three times its current Northeast US domain, to include the Gulf Coast states and the Mississippi Valley as far west as the Texas Panhandle. This larger domain enables state and local agencies in thirteen additional states to issue enhanced and more geographically specific ozone air quality warnings to the public. The new AQFS also included improved air quality forecast algorithms for cloudy conditions. The AQFS makes use of the 12 km NAM-Eta model to provide meteorological predictions that the Environmental Protection Agency-NOAA/OAR

CMAQ (Community Multi-scale Air Quality) model uses to produce hour-by-hour ozone forecasts through midnight of the following day (48 hours) at 5 km horizontal resolution. This expanded ozone forecast guidance is one step in building a national air quality forecast capability that will continue over the next decade, with coverage expanding to the entire nation within four years.

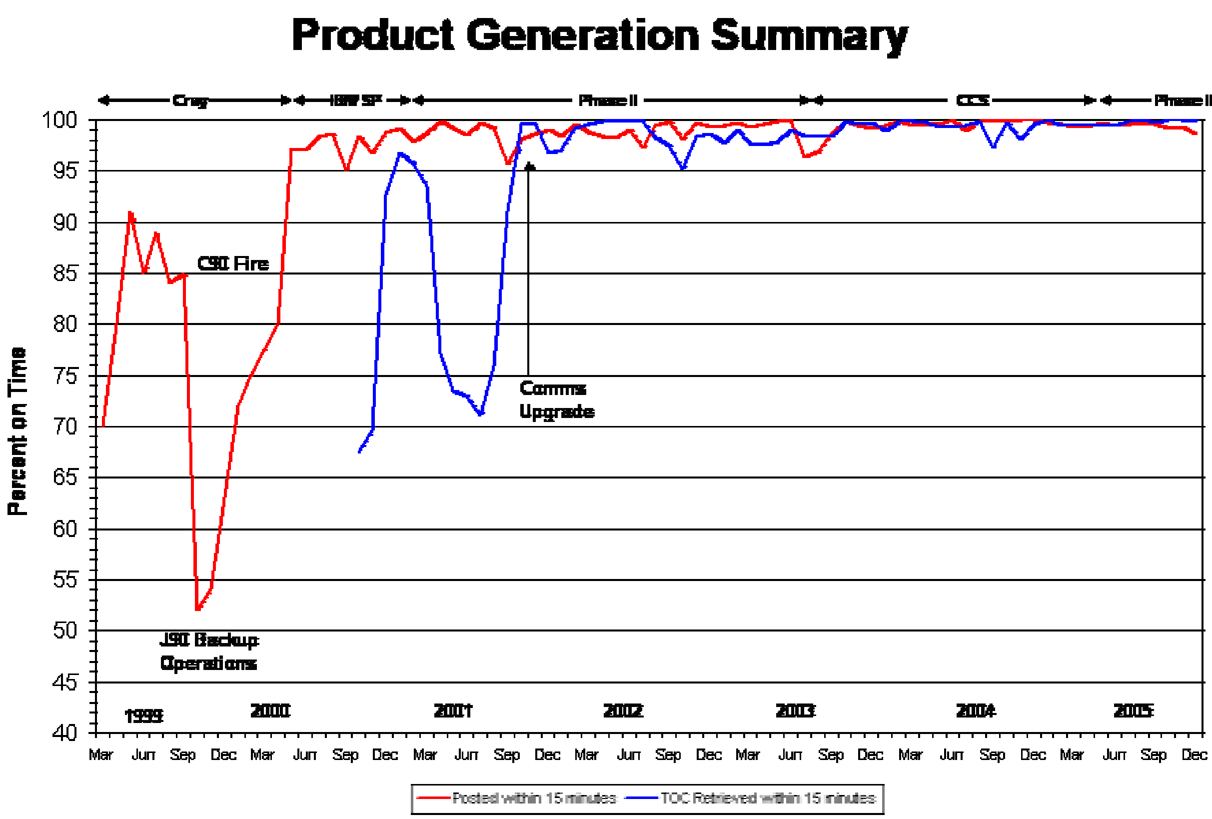
September 27, 2005: NCEP implemented upgrades to its Real-Time Global Sea Surface Temperature (RTG_SST) analysis and Genesis Cyclone Tracker software. RTG_SST increased its horizontal resolution from a half-degree (latitude, longitude) grid to a 1/12 degree grid. NCEP's Genesis Cyclone tracker program was expanded to track subtropical and extratropical storms as well as tropical cyclones. RTG_SST is produced daily using a two-dimensional variational interpolation analysis of the most recent 24-hours buoy and ship data, satellite-retrieved SST data, and SST's derived from satellite-observed sea-ice coverage. Genesis Cyclone Tracker uses output data from the NAM-Eta, GFS, NOGAPS (Navy Operational Global Atmospheric Prediction System), UKMET and GFS Ensemble models to identify tropical, subtropical and extratropical cyclones and track their positions as a tool to aid forecasters. Genesis Cyclone Tracker covers four tropical regions (Atlantic, Eastern Pacific, Central Pacific and Western Pacific) and the subtropical (mid-latitude) oceans.

December 6, 2005: The NCEP Short Range Ensemble Forecast (SREF) system was upgraded by adding 6 Weather Research and Forecasting (WRF) model members to the current 10 NAM-Eta model members and 5 Regional Spectral Model (RSM) members, to help capture uncertainties resulting from the incomplete specification of initial conditions, model physics, and numerics and dynamics in the operational SREF system. The 6 WRF members are made up of three using the Advanced Research (ARW) WRF core (50 km/35 levels) and three with the Non-hydrostatic Mesoscale Model (NMM) core (40 km/50 levels) and physics. Both deterministic and probabilistic verification statistics have shown that the upgraded SREF provides improved accuracy and forecast spread (uncertainty) information, especially for key weather elements. In addition, several key products were added to the SREF gridded output files to provide new guidance on winter weather forecast scenarios, such as the possibility of roadway icing and reduced visibility.

December 13, 2005: The NCEP ROFS model was replaced by the Real Time Ocean Forecast System (RT-OFS) at 0400 GMT. RT-OFS (Atlantic – 25 levels) provides NCEP customers with substantially improved ocean products compared to the current operational ROFS products. RT-OFS increases NCEP ocean model coverage from ROFS' North West Atlantic at 15 km resolution to the entire Eastern seaboard waters of the US (including its territories) at 4-7 km resolution. RT-OFS will provide a 1-day 'nowcast' of the ocean and a 5-day forecast, extending the 1-day nowcast and 2-day forecast provided by ROFS. RT-OFS replaces the ROFS Princeton Ocean Model with the University of Miami Hybrid Coordinate Ocean Model (HYCOM), the state of the art in depicting the three-dimensional ocean state at fine resolution in real time. RT-OFS will provide initial and boundary conditions for the ocean model within the coupled hurricane model, and initial and boundary conditions for the high resolution regional (physical and bio-geo-chemical) models of NOAA/NOS (National Ocean Service) and US regional ocean observing systems such as SEACOOS (Southeast U.S. Atlantic Coastal Ocean Observing System) and GoMOOS (Gulf of Maine Ocean Observing System). RT-OFS (Atlantic) is the first of a series of NCEP real-time regional ocean forecast system implementations over the next decade.

1.2 Operational Performance of the Production Forecast Suites

On-time production of numerical forecast products fell slightly in 2005 to an average of 99.42, down from 99.71 in 2004. Reliability of receipt of products at the NWS Telecommunication Gateway continued to improve, increasing to 99.74% in 2005 from 99.28% in 2004. Even though there were no major disruptions in product generation in 2005, maintaining operations with a backup system in a geographically separate region provided several new challenges throughout the year. The average time to switch operations between the primary and backup systems in 2005 was 20 minutes, which is beyond the 15 minute threshold for on-time product generation. This switch-time, coupled with a number of performance issues on the backup system, resulted in average monthly reliability performance ranging from 98.62 to 99.75%.



2. Equipment

2.1 IBM Regatta Cluster

The disk space available to the computer facilities at IBM Gaithersburg, MD and at the NASA IV7V facility in Fairmont, West Virginia was expanded to 44 TB at each site in 2005. The current configuration of the IBM CCS is contained in Table 1.

Table 1. IBM Systems

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

2.2 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. 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).

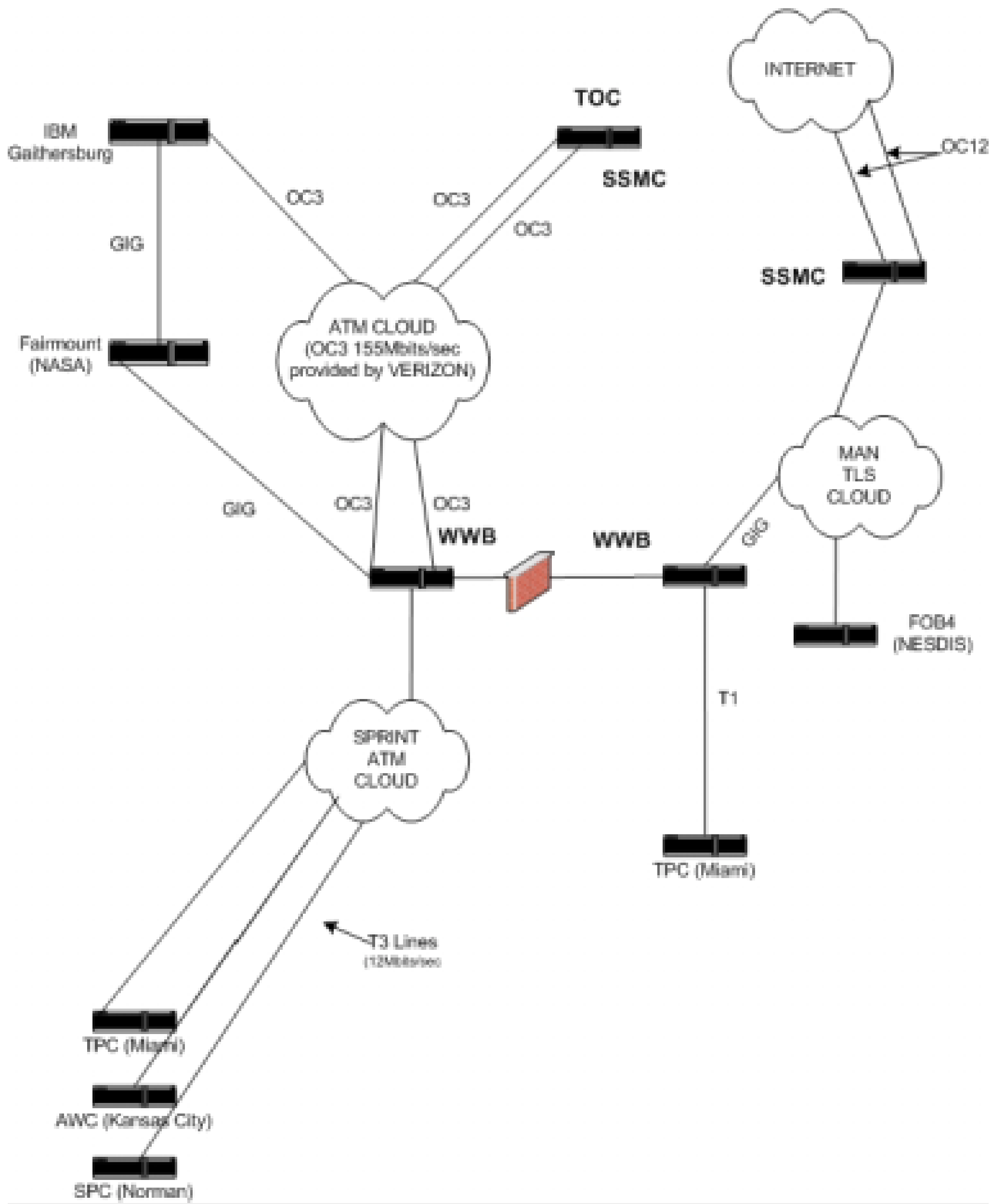


Figure 2. NCEP Network Configuration - 2005

3. Observational Data Ingest and Access System

3.1 Status at the End of 2005

3.1.1 Observational Data-Ingest

All observations for assimilation are stored in accumulating data files in WMO BUFR (**B**inary **U**niversal **F**orm for the **R**epresentation of meteorological data) format according to their WMO BUFR data type and local subtype. Atmospheric observational data in 24 hour "tank" files (based on report time) 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 at least 31 days. Observational data in 1 month "tank" files (consisting of some oceanographic data) remain on-line for at least 6 months before migration. While online, there is open access to them for accumulating late arriving observations and for research and study.

The various NCEP networks access the observational data base at a set time each day (the data cutoff time) and perform a time-windowed dump of requested observations. Observations of a similar type [e.g. satellite-derived winds ("satwnd"), surface land reports ("adpsfc")] are dumped into individual BUFR files that maintain the original structure of the reports, although some interactive quality control is applied (see 4.1.1), duplicate reports are removed, and upper-air report "parts" are merged.

The final step in preparing most of the non-satellite observational data for assimilation involves the execution of a series of programs which read in the observations from the various dump files, add forecast ("first guess") background and observation error information, perform automated quality control (see 4.1.2), and finally output the observations in a monolithic BUFR file known as "PREPBUFR". Most of the satellite data do not go through the PREPBUFR processing; they are assimilated directly from their dump files.

Changes to Data Ingest in 2005:

January 25, 2005: The program that performs quality control functions on non-automated (AIREP and PIREP) aircraft data and track checking on automated AMDAR aircraft data was modified to increase the maximum temperature where it is flagged for non-use by the assimilation from 12 to 32 degrees Celsius. This allows reasonable low-level temperatures to be assimilated. The program was also modified to increase the number of reports that can be processed from 20,000 to 40,000 in response to an increased number of AMDAR reports [including the new European AMDAR (E-ADAS) reports].

January 25, 2005: The program which encodes observational data into the Prepared BUFR (PREPBUFR) files, in preparation for their quality control and assimilation into NCEP analyses, was modified to allow the processing of mobile surface synoptic land reports and European AMDAR (E-ADAS) aircraft reports for assimilation into the global and regional analyses. In addition, the following new types of data were added for future assimilation into operational NCEP analysis: Mesonet surface data, GPS-Integrated Precipitable Water data, NOAA Profiler Network and Cooperative Agency Profiler Radio Acoustic Sounding System (RASS) virtual temperature data, Cooperative Agency Profiler winds, Japanese Meteorological Agency profiler winds, and Aqua and Terra MODIS satellite-derived IR and water vapor winds. Processing of GOES picture triplet cloud drift winds ended. Sea surface temperature observations from all available sources were now encoded in the PREPBUFR file (for testing by the future GSI analysis), and sensible weather elements (visibility, past and present weather, peak wind speed and direction, total precipitation over various time intervals, information about clouds, snow depth, wave information, pressure tendency, max/min temperature) were now encoded into all network PREPBUFR files (for verification purposes).

January 25, 2005: A new job was added to dump forward-averaged AIRNOW ozone concentration data from the previous day for use in the EPA Air Quality Forecast model verification at NCEP.

January 25, 2005: The program that performs complex quality control of profiler winds was modified to correct long-standing errors, to account for new Cooperative Agency Profiler and Japanese

Meteorological Agency wind profiler reports, to improve the quality control algorithm, to improve documentation, and to provide more meaningful output information.

January 25, 2005: A new release of the NCEP BUFR archive library (BUFRLIB) was implemented into operations.

February 22, 2005: The program which applies interactive quality control flags and corrections to marine data was modified to increase the number of reports it can process from 25,000 to 50,000 in response to an increased number of drifting buoy reports. In addition, the amount of latitude/longitude round-off used in matching reports in the flag file to those in the BUFR dump file was increased from 0.001 to 0.01 degrees to allow for differences in round-off between the upstream CREWSS processing results and the BUFR dump. This had resulted in some reports not being quality controlled by this program.

February 22, 2005: The program that ingests NAVY and NESDIS sea surface temperature retrievals (derived from AVHRR) into the NCEP BUFR files was modified to include 24-hour averaged GOES sea surface temperature data from NESDIS.

March 15, 2005: A CRISIS change was implemented to the program which checks satellite data for duplicates in the data dumping process in response to a NESDIS change to correct the BUFR encoding of satellite instrument type used in data processing.

March 29, 2005: The program which ingests satellite-derived wind reports into NCEP BUFR files was modified to encode additional quality information for Terra and Aqua POES MODIS winds. These are not yet assimilated by any operational NCEP analyses but are available for model data impact tests.

April 19, 2005: CMAN-formatted tide gauge data were introduced into the NCEP BUFR data base (these data are not yet dumped or assimilated by any NCEP operational analysis).

April 26, 2005: The program which ingests HIRS-3 data from NOAA-15-17 into NCEP BUFR was modified to account for an upcoming 1B format change by NESDIS.

May 03, 2005: WSR-88D NEXRAD Level 2.5 radial wind on-site superobs were added to the operational NAM dump processing and are now assimilated by the Eta 3DVAR as part of the Winter 2005 Eta bundle implementation. These data have more tilt angles and are at higher precision than the Level 3 radial wind superobs. In addition, unlike the Level 3 data, the Level 2.5 data are not thinned near the radar sites. The Level 3 radial wind data will be used as a backup to the Level 2.5 data in the Eta 3DVAR.

May 31, 2005: The GFS and GDAS analyses were modified to assimilate Aqua AIRS IR and AMSU-A brightness temperatures.

June 7, 2005: High-resolution EUMETSAT visible and cloud-top water vapor satellite-derived winds; Japanese IR, visible and water vapor satellite derived winds; and GOES IR, visible and water vapor winds obtained from the GTS were introduced into the NCEP BUFR data base (these data are not yet dumped or assimilated by any NCEP operational analysis, the analysis does assimilate EUMETSAT IR winds; Japanese IR and visible winds originating in SATOB format; and GOES IR and water vapor winds in BUFR obtained from an in-house NESDIS server).

June 21, 2005: The program which ingests AMSU-A data from NOAA-15-17 into NCEP BUFR files was modified to store uncorrected antenna temperatures into a unique data base file for use by NCEP/TPC. (The corrected AMSU-A brightness temperatures are assimilated by the operational NCEP Global SSI and Eta 3DVAR analyses.)

June 21, 2005: NCEP/NCO implemented a web-based Real Time Data Monitoring System as a new observation receipt monitoring tool. It will be used primarily by the NCO/SDM to track low or missing observational data sources, noting which sources are critical data types.

June 28, 2005: The RUC analysis was modified to assimilate mass data from surface mesonet reports (wind still not assimilated), RASS virtual temperature observations, and GPS-IPW.

July 12, 2005: A change was made to dump 1- and 8-hour backward-averaged AIRNOW ozone concentration data in place of forward-averaged data. This change streamlines the use of these data in the EPA Air Quality Forecast model verification at NCEP. The 1- and 8-hour backward-averaged AIRNOW ozone concentration data were introduced into the NCEP BUFR data base on June 7, 2005.

July 13, 2005: A CRISIS change was implemented to flag dropwinsonde winds on all levels for reports "sufficiently close" to tropical storms. Sufficiently close is defined as the larger of three times the radius of maximum winds for the tropical storm or 111 km. These dropwinsonde winds will no longer be assimilated by either the NCEP Global SSI or the Eta 3DVAR analyses, as the use of these data can degrade the analysis and subsequent forecast of tropical systems.

July 21, 2005: A CRISIS change was implemented to increase the Eta 3DVAR observation error for GOES layer precipitable water retrievals from 8 to 16 mm and for SSM/I total column precipitable water retrievals from 8 to 12 mm to better reflect the quality of these satellite data, especially the fact that off-time retrievals have been found to have a higher moist bias.

July 21, 2005: A CRISIS change was implemented to the program that checks satellite data for duplicates in the data dumping process in response to the Japanese Meteorological Agency's platform switch from GOES-9 to MTSAT-1R for their satellite-derived winds.

August 17, 2005: Four new Mesonet types (DC-Net, Indiana DOT, Florida DOT and Alaska DOT) were introduced into the NCEP BUFR data base and 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. In addition, soil moisture tension and soil temperature were added where present in the input data.

August 17, 2005: The method for acquiring Mesonet data was modified to use a new "LDM-to-LDM" method between FSL and NCEP, as opposed to the old "ftp push" method. This resulted in much quicker data receipt times than before and increased the number of data available in the early-cutoff RUC and NAM dumps.

August 23, 2005: The program which calculates and applies intersonde (radiation) temperature and height bias corrections to rawinsonde reports was modified to update the current temperature correction table for China's Shanghai Radiosonde so temperature corrections will no longer be applied at and below 50 mb. This change should remove most of a strong cold bias in these sondes below 50 mb since China began applying on-site corrections over one year ago. Corrections will still be made below 50 mb for Shanghai Radiosondes launched prior to 1 July 2004 (in historical reruns).

August 23, 2005: The programs which ingest ATOVS (previously NOAA-15-17) instrument 1B radiance data into NCEP BUFR files were modified to also process NOAA-18 HIRS-4, MHS and AMSU-A data. The NOAA-18 AMSU-A data were also dumped in the NAM, NDAS, GFS and GDAS networks.

August 23, 2005: High-resolution EUMETSAT clear sky (deep layer) water vapor satellite-derived winds were introduced into the NCEP BUFR data base. These data are yet assimilated by any operational NCEP analyses but are available for model data impact tests.

August 31, 2005: A CRISIS change was implemented to the program which calculates air pollution potential, Lifted Index, and precipitable water from North American rawinsonde reports (for later graphical output) to correct errors resulting from an increased number of reported significant levels. This is a result of the initial site implementation of the new Radiosonde Replacement System (RSS) software at Sterling, VA (72403) on 10 August. A follow-up CRISIS change was necessary to this program on October 4, 2005 in order to further account for the increased number of U.S. sites using the RSS software.

September 27, 2005: USGS River and Stream flow data were introduced into the NCEP BUFR data base.

September 27, 2005: NESDIS POES sea surface temperature, AVHRR brightness temperatures and albedo, NAVY POES high-resolution sea surface temperature, AVHRR brightness temperatures and albedo, NAVY POES physical sea surface temperature retrievals (obtained from the GSI analysis), and NESDIS POES physical sea surface temperature retrievals (from the GSI analysis) were introduced into the NCEP BUFR data base.

September 27, 2005: A package was implemented in order to provide a dump interface with the MODS (marine observations with 31-day late cutoff) BUFR data base.

October 11, 2005: The program that ingests GOES clear sky (imager) brightness temperature data from the University of Wisconsin/CIMSS into NCEP BUFR files was modified to acquire the data from a new Linux machine at UW/CIMMS. These data are not yet assimilated by any operational NCEP analyses but are available for model data impact tests.

October 11, 2005: The program that ingests HIRS-3 data from NOAA-15-17 and HIRS-4 data from NOAA-18 into NCEP BUFR files was modified to correct an error in a previous implementation (April 26, 2005) related to the HIRS-3 1B format change by NESDIS. In addition, the program was changed to redefine its interpretation of calibration quality bit settings in the input NESDIS HIRS-4 1B format files, to prevent the rejection of nearly all NOAA-18 HIRS-4 scan lines.

October 11, 2005: A change was made to dump 1- and 8-hour backward-averaged AIRNOW ozone concentration data twice in each run to process data for both the previous day (as before) and also for five days prior to the current day. This change will allow the NCEP Air Quality Forecast model verification to use data that had to be resent in full after the fact by EPA to NCEP.

October 11, 2005: The program that ingests ATOVS SBUV (ozone) data into NCEP BUFR files was modified to include data from NOAA-18. These data are in both daily files for use by NCEP/NPC and dump files used by the Global SSI. The NOAA-18 SBUV data are not yet assimilated by any operational NCEP analyses but are now available for model data impact tests.

October 18, 2005: The program that ingests Aqua AIRS IR and AMSU-A data into NCEP BUFR files was modified to process both the new warmest (clearest) field-of-view (f-o-v) AIRS IR and AMSU-A radiance data, and Aqua AMSR-E radiance data. The central f-o-v AIRS data are assimilated by the operational NCEP Global SSI analysis. On October 26, 2005 a change was made to dump both of these new types in the GFS and GDAS networks. These data are not yet assimilated by any operational NCEP analyses but are available for model data impact tests.

October 26, 2005: The satellite duplicate-checking and data-counting programs were modified to reduce (by 5-fold) the amount of computation time for data dump processing of compressed satellite BUFR messages (e.g., the ATOVS and AVHRR 1B radiances and AIRS and AMSR-E radiances).

October 26, 2005 The program that ingests HIRS-3 data from NOAA-15-17 and HIRS-4 data from NOAA-18 into NCEP BUFR files was modified to also dump the NOAA-18 HIRS-4 and MHS data in the NAM/GFS networks. These NOAA-18 radiance data are not yet assimilated by any operational NCEP analyses but are available for model data impact tests.

November 29, 2005: The GFS and GDAS analyses were modified to assimilate NOAA-17 SBUV layer and total ozone, NOAA-18 AMSU-A brightness temperatures, and Aqua and Terra MODIS satellite-derived IR and water vapor winds.

December 6, 2005: The program that ingests GOES clear sky (imager) brightness temperature data into NCEP BUFR files was modified to use input files produced by NESDIS and residing on their server, replacing UW/CIMSS files mirrored to NESDIS from a UW/CIMSS server. This change is in response to these data being deemed "operational" by NESDIS. These data are not yet assimilated by any operational NCEP analyses but are available for model data impact tests.

December 6, 2005: A change was made to copy the output files from the dump of 1- and 8-hour backward-averaged AIRNOW ozone concentration data for both the 1- and 5-day data (see October 11) into the current day's directory file instead of the dump date's directory file on the NCEP CCS. This change will allow the five-day-old data to be retained longer on-line, mirrored to the development NCEP CCS machine, and archived to the NCEP High Performance Storage System (HPSS).

December 6, 2005: The tropical cyclone synthetic data bogusing program was modified to account for tropical systems with a reported radius of the outermost closed isobar exceeding 800 km. Previously, this program would fail silently when attempting to generate bogus data for these extremely large storms.

December 13, 2005: A package of programs designed to ingest WSR-88D NEXRAD Level II radial wind and reflectivity data into the NCEP BUFR files in the developmental data base and dump these data in the NAM and NDAS networks was implemented in the NCEP parallel processing system. The ingest step includes a radial wind quality control module designed at NSSL. This processing is likely to be moved into operations in late Winter 2006 in preparation for the operational implementation of the Level II radial wind data in the Regional-GSI analysis.

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, dropwinsonde) temperature and moisture data; upper-air profile (rawinsonde, PIBAL, dropwinsonde, wind profiler, VAD) wind 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 SDMs is only applied selectively in cases where there are indications of egregious errors.

NCEP/NCO also has the ability to place data on a "reject' list based on monthly quality monitoring procedures or on feedback from other NWP centers or from data producers themselves. These "rejected" data will not be assimilated but they will be available for monitoring.

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 hydrostatic 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. In early 2006, the aircraft quality control algorithms will be replaced with a new program based on aircraft quality control procedures developed at the Naval Research Laboratory (NRL). The NRL program is more comprehensive than the current aircraft quality control programs in use at NCEP. For example, it will provide full quality control of all aircraft types, including MDCRS ACARS data, and it will perform track checking across all aircraft platforms. As a final step in this new algorithm, NCEP will combine the dense single-level MDCRS ACARS and AMDAR ascent and descent reports for each unit into a profile report (one for ascent and one for descent) which will then look much like a rawinsonde report. Profile reports are better suited to both assimilation and verification procedures.

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 checks 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 2005

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 2005 are shown in Tables 2 and 3. The "Percent Input" listed in the right-hand column represents the percentage contribution of each category to the total data count.

Note on PERCENT OUTPUT column: In Table 2a., the number on left is the percentage of all non-satellite data contributed by a data category (subtotal). The number in parentheses is the percentage of all data (satellite and non-satellite) contributed by a data category. In Table 2b., the number is the percentage of all data contributed by each category of satellite data.

Table 2a. Average Daily Non-Satellite Data Counts for December 2005
for the Global Data Assimilation System

Category	Subcategory	Total Input	Percent Input
Land Surface	Synoptic	60084	*
	METAR	138071	*
	subtotal	198155	49.1 (0.11)
Marine Surface	Ship	2756	*
	Drifting Buoy	30930	*
	Moored Buoy	5071	*
	CMAN	2411	*
	Tide Gauge	3169	*
	subtotal	44337	11.0 (0.02)
Soundings	Fixed RAOB	1395	*
	Ship RAOB	16	*
	Dropsonde	2	*
	Pibal	319	*
	Profiler	1113	*
	VAD Winds	6055	*
	subtotal	8900	2.2 (0.005)
Aircraft	AIREP	4465	*
	PIREP	1019	*
	AMDAR	42676	*
	ACARS	103882	*
	RECCO	6	*
	Subtotal	152048	37.7 (0.08)
Total	Non-Satellite	403440	100.0 (0.22)

Table 2b. Average Daily Satellite Data Counts (RECEIVED) for December 2005
For the Global Data Assimilation System

CATEGORY	SUBCATEGORY	TOTAL INPUT	PERCENT INPUT
Satellite soundings	GOES	1567415	0.85
Ozone	OZONE	64386	0.034
Satellite winds	SATWND	100576	0.055
Scatterometer winds	QUIKSCAT	5784063	3.14
DMSP	SSMI NEURAL NET	623540	0.34
*	SSMI RAINFALL RATES	2111004	1.14
Satellite surface	NASA TRMM DATA	9170145	4.97
Satellite radiances	HIRS2 1B	5526173	3.00
*	HIRS3 1B	13466155	7.30
*	MSU 1B	5526173	3.00
*	AMSUA 1B **	13479809	7.31
*	AMSUB 1B	40937788	22.19
*	AIRS	86091066	46.67
Total	Satellite Received	184448293	99.78

** Counts include AMSUA radiances from the AQUA satellite

Table 2c. Average Daily Satellite Data Counts (SELECTED) for December 2005
For the Global Data Assimilation System

CATEGORY	SUBCATEGORY	TOTAL INPUT	PERCENT INPUT
Satellite soundings	GOES	69545	*
Ozone	OZONE	30645	*
Satellite winds	SATWND	100576	*
Scatterometer winds	QUIKSCAT	1386510	*
DMSP	SSMI NEURAL NET	623540	*
*	SSMI RAINFALL RATES	2111004	*
Satellite surface	NASA TRMM DATA	9170145	*
Satellite radiances	HIRS2 1B	280033	*
*	HIRS3 1B	87566	*
*	MSU 1B	280033	*
*	AMSUA 1B **	1956536	*
*	AMSUB 1B	261794	*
*	AIRS	7561413	*
Total	Satellite Selected	23919340	*

** Counts include AMSUA radiances from the AQUA satellite

Table 2d. Average Daily Satellite Data Counts (ASSIMILATED) for December 2005
For the Global Data Assimilation System

CATEGORY	SUBCATEGORY	TOTAL INPUT	PERCENT INPUT
Satellite soundings	GOES	17315	*
Ozone	OZONE	30449	*
Satellite winds	SATWND	100576	*
Scatterometer winds	QUIKSCAT	462170	*
DMSP	SSMI NEURAL NET	623540	*
*	SSMI RAINFALL RATES	117278	*
Satellite surface	NASA TRMM DATA	868967	*
Satellite radiances	HIRS2 1B	34470	*
*	HIRS3 1B	57073	*
*	MSU 1B	34470	*
*	AMSUA 1B **	1243357	*
*	AMSUB 1B	168312	*
*	AIRS	2159684	*
Total	Satellite Assimilated	5927661	*

** Counts include AMSUA radiances from the AQUA satellite

6. Forecasting System

6.1 Global Forecast System

6.1.1 Status of the Global Forecasting System at the End of 2005

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 6-hour data cut-off times. NOAA-16 HIRS/3 observations were turned off in the Global Data Assimilation System (GDAS) in May. AQUA-AIRS observations were added 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 180 hours is T382L64, and T190L64 from 180 to 384 hours. The Global Forecast System (GFS) model was upgraded in May to include changes in the land (NOAH) and sea-ice model, reduced vertical diffusion in the free atmosphere, and a modification to the sub-grid scale mountain drag formulation.

c) The Global Ensemble System (GENS) consists of ensembles of global 16-day forecasts from perturbed FNL initial conditions (ten forecasts each from 0000, 0600, 1200, 1800 UTC). Ensembles are run at T126-resolution for the entire 16 days (prior to August, T126 changed to T62 at forecast hour 180 hours). The system provides improved 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.

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, ozone mixing ratio, cloud water/ice, and the natural logarithm of surface pressure (ln psfc). All global analyses are done on 64 sigma levels at a T382 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, ozone 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 truncated (triangular) at T382. 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 12 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;

6.1.2 Future Plans for the Global Forecasting System

Changes planned for the production suite include:

a) Upgrade GDAS and GFS to use GSI analysis and hybrid sigma-pressure vertical coordinate;

b) Upgrade GDAS to include a new SST analysis, improved us of AIRS data, and MODIS winds;

c) Upgrade global ensemble to include ETKF and a membership increase;

e) 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.

f) Continue to participate in THORPEX activities;

g) Implement standard FVS-based verification system in GFS and GENS;

h) Provide GFS meteorological fields through a common post-processor for all EMC models; and

i) Implement ESMF (Earth System Modeling Framework) compliant GFS.

6.2 Regional Forecast System

6.2.1 Status of the Regional Forecasting Systems at the End of 2005
Regional Forecast System Configuration:

The Regional Systems are:

a) The North American Mesoscale Forecast System (NAM, formerly 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 Eta forecast model and the NAM Data Assimilation System (NDAS, formerly EDAS, see below) were updated in May 2005. This changes to the data assimilation consist of the use of a 2DVAR module in the NAM 3DVAR to analyze surface land temperature data (which were turned off in 2003 due to adverse impact of Eta model forecasts), assimilation of Level II.5 NEXRAD radial wind data, and the use of a "scaled-back" precipitation assimilation algorithm which is less aggressive in modifying Eta model precipitation during the NDAS, but uses the hourly observed precipitation as is to drive the Eta model land-surface physics. Modifications to the Eta model forecast component of the NAM include changes to the Land-surface model (use 1 km resolution soil and vegetation types, replace GFS-based bottom soil temperatures with new database from ECMWF, changes to alleviate winter nighttime cold biases over snow cover and daytime biases over melting snow, changes to alleviate summer warm/dry daytime bias). The Eta model cloud and radiation physics were changed to allow for more partial cloudiness and to allow thicker clouds to influence model radiation. These changes are described

at
http://wwwt.emc.ncep.noaa.gov/mmb/mmbpll/Spring2005.NAMUpgrade_newweb/Spring2005.NAMUpgrade.html ;

b) The Rapid Update Cycle (RUC) System generates high-resolution analyses and 9-hour forecasts for the contiguous United States every hour with forecasts extended to 12-hrs at 0000, 0300, 0600, 0900, 1200, 1500, 1800, and 2100 UTC . On June 28, 2005 a package of model and analysis changes was implemented. The model changes included an upgrade to 13 km horizontal resolution (maintaining 50 vertical levels), modifications to the microphysics, a revised simulation of radiation/cloud impacts, updates to the convective parameterization, and a corrected treatment of frost formation. Analysis changes included the assimilation of new observations (GPS precipitable water, mesonet observations, and METAR cloud, visibility, and current weather reports), the nudging of soil temperature and moisture, and the change of control variable for moisture from logarithmic specific humidity to pseudo- relative humidity. These changes have significantly improved moisture, cloud, and visibility analyses and forecasts;

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) The NCEP Short Range Ensemble Forecast (SREF) system provides multiple model short-range (0-3 day) ensemble predictions that offer operationally relevant and useful guidance on probabilities of occurrence for various potential weather elements or events. The probabilistic information provided by SREF will help meet the NWS strategic goal of providing probabilistic gridded products to the NWS/WFOs, service centers and other users. In December, the SREF was upgraded by adding 6 Weather Research and Forecasting (WRF) model members to the current 10 NAM-Eta model members and 5 Regional Spectral Model (RSM) members, to help capture uncertainties resulting from the incomplete specification of initial conditions, model physics, and numerics and dynamics in the operational SREF system. The 6 WRF members are made up of three using the Advanced Research (ARW) WRF core and three with the Non-hydrostatic Mesoscale Model (NMM) core and physics. Both deterministic and probabilistic verification statistics have shown that the upgraded SREF provides improved accuracy and forecast spread (uncertainty) information, especially for key weather elements. In addition, several key products were added to the SREF gridded output files to provide new guidance on winter weather forecast scenarios, such as the possibility of roadway icing and reduced visibility. More information on this implementation can be found at:
http://wwwt.emc.ncep.noaa.gov/mmb/SREF-Docs ;

e) A pair of High Resolution Window (HiResW) nested runs, one using the WRF version of the Non-hydrostatic Meso Model (NMM), the other using the NCAR Advanced Research WRF (WRF-ARW, formerly WRF-EM) are made following the completion of the GFS run suite. These runs get boundary conditions and their initial conditions from the parent continental domain NAM runs (see above).The schedule for these runs is : 00Z : Alaska , Hawaii; 06Z : Western U.S., Puerto Rico; 12Z: Central U.S., Hawaii; 18Z: Eastern U.S., Puerto Rico. In June these HiResW runs were change by changing the resolution of the WRF-NMM from 8 km / 60 levels to 5.1 km / 35 levels and changing the resolution of the WRF-ARW from 10 km / 50 levels to 5.8 km / 35 levels. Convective parameterization was turned off in both runs. Since these HiResW forecasts run in the NCEP production slot reserved for the GFDL hurricane model, this is the new HiResW operational configuration:

- No hurricane runs : Both large and small WRF-NMM and WRF-ARW domains are run by NCEP Central Operations
- One or two hurricane runs : Large domain WRF-ARW is canceled by NCEP Central Operations

- Three hurricane runs : Both large domain WRF-NMM and WRF-ARW runs canceled by NCEP Central Operations,, EMC runs large domain WRF-NMM on development computer
- Four hurricane runs : All WRF HIRESW runs canceled by NCEP Central Operations, EMC runs both large and small domain WRF-NMM on development computer;

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 NAM 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 HiResW nests. There are 21 overlapping grids covering the CONUS plus 5 grids covering Hawaii, Juneau, Fairbanks, Anchorage and Puerto Rico;

g) The NCEP Air Quality Forecast System (AQFS) provides 48 h forecasts for the Northeastern US, satisfying the operational requirements of accuracy and timeliness during the ozone season (June 1 - September 30), when ozone concentrations peak during hot, dry, stagnant summertime conditions. This forecast guidance is sent in gridded form to EPA for distribution to official forecasters at the individual state level. AQFS has at its core the mesoscale NAM-Eta model and the Community Multiscale Air Quality (CMAQ) model from the Environmental Protection Agency (EPA). CMAQ (12 km/22 levels) is driven by 12 km meteorological fields from the NAM-Eta forecasts. In early September, the AQFS domain was expanded to cover the entire eastern half of the US. This larger domain enables state and local agencies in thirteen additional states to issue enhanced and more geographically specific ozone air quality warnings to the public;

h) A new Downscaled GFS with Eta extension (DGEX) run, made after the 84-h NAM forecast, is an extension of the Eta model forecast 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 NAM and receive lateral boundary conditions from the previous GFS forecast. Since the domain has been reduced (to fit the run into the available run slot), 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 WFOs 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. In May the Eta model changes made in the NAM (land-surface, cloud, and radiation physics, see above) were also implemented in the DGEX.

<u>Regional Forecast System Data Assimilation:</u> Initial conditions for the four Meso Eta Model 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. The data time window radius is 1.5 hours about the center of the data dump cycle time. No initialization is applied. In 2005 a parallel data assimilation system is being tested with the same setup as the EDAS. The new system, the NMM-based Data Assimilation System or NDAS, uses WRF-NMM forecast model and the Gridpoint Statistical Interpolation (GSI) analysis. An adaptive tuning procedure is used to adjust the observational error covariance which reflects current model resolution and observational accuracy. A new analysis variable for the humidity field: normalized relative humidity is implemented. With the choice of the new analysis

variable, the possibility of supersaturation and negative humidity generated by analysis is effectively eliminated and the humidity analysis is multi-variated related with temperature and pressure.

<u>Regional Forecast System Models:</u> 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. The integration is split explicit. Fast waves (inertial gravity) are solved using the forward-backward scheme and advection of T, u, and v uses a first-forward-then-backward off center scheme. 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-Schwarzkopf 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. Prior to 28 June 2005 the vertical domain was 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. As of 28 June the number of layers in the HiRes run was reduced to 35 while the horizontal gridpoint spacing was increased from 8 km to 5.1km. The Arakawa E-grid is used 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/implicit approach in 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-Schwarzkopf / 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 5.1 km HiRes runs do not use any convective parameterization. The lateral boundary conditions are derived from the current Meso Eta model forecast at a 1-hour frequency for Fire Weather and a 3-hour frequency for HiRes.

The WRF ARW (Advanced Research WRF) formerly known as the WRF Eulerian Mass-core (EM) Model was developed by NCAR (used for HiRes runs and Short Range Ensembles) uses 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 ARW 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. As of 28 June 2005 the gridpoint spacing for the WRF ARW HiRes runs was reduced from 10 km to 5.8 km and convective parameterization was turned off.

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 cutoff 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.

<u>Regional Forecast System Products:</u> 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 9 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.

g) A complete catalogue of NCEP numerical and graphic products is available at http://www.nco.ncep.noaa.gov/pmb/products

<u>Operational Techniques for Application of Regional Forecast System Products:</u> 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 2006 Goals

a) Begin assimilating surface mesonet data (Eta/EDAS);

b) Begin assimilating GPS Integrated Precipitable Water (GPS-IPW) data (Eta/EDAS);

c) Begin assimilating Cooperative Agency (CAP) wind profiler data (in addition to NOAA Profiler Network data now assimilated);

d) Begin assimilating Cooperative Agency (CAP) and NOAA Profiler Network Radio Acoustic Sounding System (RASS) data (Eta/EDAS);

e) Begin assimilating Canadian AMDAR and TAMDAR aircraft data as well as aircraft moisture observations from the WVSS-II sensor;

f) Begin assimilating quality-controlled WSR-88D NEXRAD Level II radial wind data (and monitor quality-controlled WSR-88D NEXRAD Level II reflectivity wind data) (Eta/EDAS);

g) Replace the ETA model with the MRF NMM model by June, 2006.

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 in the Climate Forecast System (CFS). There are two runs of the GODAS daily. The first one is a 14-day lagged GODAS to get the maximum data coming into the NCEP tank. The second one is a 7-day lagged GODAS used to initialize the CFS.

b) The NCEP ROFS model was replaced by the Real Time Ocean Forecast System (RT-OFS) on 13 December. RT-OFS is based on the Hybrid Coordinate Ocean Model (HYCOM), which is run to produce 1- and 5-day forecasts at 4-7 km horizontal resolution with 25 vertical ocean levels over the entire Eastern seaboard waters of the US (including its territories). The ocean initial conditions for each forecast cycle are created by advancing the initial conditions of the previous forecast cycle to the current time with forcing fields from 3-hour NCEP (GDAS/GFS) model and assimilation of in-situ and satellite derived SST's, daily river outflow observations from USGS, and sea surface height anomalies derived from altimeters. RT-OFS will provide initial and boundary conditions for the ocean model within the coupled hurricane model and initial and boundary conditions for the high resolution regional (physical and bio-geo-chemical) models of NOAA/NOS and US regional ocean observing systems such as SEACOOS and GoMOOS. 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 towards establishing a common coupled ocean-atmosphere modeling framework that would make it possible to provide real-time forecasts on regional, basin, and global scales, as needed, in a unified and efficient manner. This new effort is using, for its ocean component, the Hybrid Coordinate Ocean Model (HYCOM) system, which is a collaborative effort involving several partners from the 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 is currently running in real-time in a pre-operational parallel mode using fluxes from NCEP's GFS model, assimilation of in-situ and satellite SST's, eight tidal constituents, and fresh water discharges. 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) A new daily real-time, high-resolution 1/12 Degree (latitude, longitude grid) SST analysis based on in-situ data and AVHRR satellite data from NOAA 16 & NOAA 17 was implemented at NCEP on September 27, 2005. This analysis was developed to better depict SST patterns for mesoscale features (i.e. Gulf Stream), coastal areas and inland lakes. The original ½ Degree SST analysis which was implemented January 30, 2001, was based on in-situ data but only with NOAA 17 retrievals. SST retrievals were retrieved using transfer functions based on regression equations. Both SST analyses are based on a two-dimension variational analysis technique with incursive filtering. The ½ Degree SST analysis was observed to contained large (0.5–1.0 C) day to day changes (noise). An alternative SST retrieval method was then developed based on a forward physical algorithm using radiances and variables of the GDAS. These new SST retrievals showed a small improvement in accuracy. When, they were tested in the new analysis, they successfully reduced the day to day (noise). Both SST products are currently distributed over the GTS, and on the Branch web page. (http://polar.ncep.noaa.gov.)

e) Daily ocean wave forecasts are produced at NCEP on a global and 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 III (NWW3) model driven by the analysis and forecast winds from the NCEP's operational Global Forecast System. In FY 2005, the following changes were made to the wave model suite. Excel friendly versions of the wave bulletins for output points were added to the web site and addition steepness measure were developed as new model output. The Great Lakes Wave model and a Global Wave model ensemble are being tested in parallel.

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 5-day forecast limit). The global WaveWatch-III (WW3) model now assimilates buoy and ERS2 altimeter data.

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.

h) Future directions for ocean models and analyses over the next 2 years:

- Add products reflecting user demand, such as additional wave steepness measures;
- Expand the wave field separation scheme to produce spatial fields of individual wave systems (Formal cooperation project with USACE);
- Start producing wave ensemble forecasts operationally;
- Couple the wave model to the hurricane model to take sea state effects on the surface into account (in HWRF);
- Operational implementation of a NWW3-based wave forecast system for the Great Lakes;
- Start evaluating the operational HYCOM-based Real-time Ocean Forecast System (RTOFS) Atlantic Basin model performance and introduce additional data assimilation procedures into the system to improve its performance;
- Develop and test a dynamical storm surge forecast model using the HYCOM Atlantic Basin model incorporating wave effects on water level and current forecasts;
- Start testing an interactive coupled RTOFS (Atlantic) and HWRF model system.

i) Future directions for ocean models and analyses beyond the next 2 years:

- 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 well known exact nonlinear 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 Hawaii regions;
- Couple global HYCOM to GFS;
- Couple the wave model to atmosphere and ocean models, starting with the HWRF development. Note that the multi-scale approach to WAVEWATCH III will be particularly important in such coupled hurricane modeling.

i) A 1-tier coupled Climate Forecast System (CFS) is run daily. 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 twice daily to 9 months. The first run uses the 00z NCEP Reanalysis-2 as atmosphere initial condition. The second set modifies the initial condition with a 10% of the difference of the two consecutive 00z analyses. A set of the daily runs are intended to be used as an ensemble.

6.4 Verification of Forecast Products for Year 2005

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 2005. Change from 2004 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	11.4 (-0.6)	27.8 (-2.6)	52.6 (-2.7)
Southern Hemisphere	14.5 (+0.1)	37.0 (-0.2)	65.9 (+0.4)
250hPa Wind RMSVE(m/sec)			
Northern Hemisphere	4.8 (+0.1)	9.8 (-0.1)	15.0 (0.0)
Southern Hemisphere	5.1 (+0.2)	10.7 (+0.3)	16.1 (+0.3)
Tropics	4.3 (+0.2)	7.1 (+0.1)	8.8 (+0.2)
850hPa Wind RMSVE(m/s)			
Tropics	2.6 (0.0)	4.1 (+0.1)	4.8 (+0.1)

Table 5. Verification against rawinsondes for 2005. Change from 2004 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	12.6 (-0.2)	29.9 (-2.7)	50.8 (-4.8)
Europe	13.9 (-2.4)	29.8 (-3.5)	55.6 (-2.4)
Asia	15.1 (+0.3)	26.8 (-1.6)	45.4 (-0.8)
Australia/New Zealand	12.8 (+0.9)	24.2 (+2.6)	40.4 (+4.0)
250hPa Wind RMSVE(m/s)			
North America	6.5 (+0.1)	11.9 (-0.1)	17.0 (-0.2)
Europe	5.8 (-0.1)	10.8 (-0.2)	17.1 (-0.2)
Asia	6.1 (0.0)	10.1 (-0.2)	14.1 (-0.1)
Australia/New Zealand	6.4 (+0.2)	10.2 (+0.6)	14.8 (+1.3)
Tropics	5.9 (+0.1)	7.6 (0.0)	8.6 (0.0)
850hPa Wind RMSVE(m/s)			
Tropics	4.2 (0.0)	5.1 (+0.1)	5.6 (-0.1)