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1985-1986 SUMMARY OF CHANGES TO NMC OPERATIONAL GLOBAL ANALYSES

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by

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I. INTRODUCTION

This is the second in a series of reports prepared to keep researchers throughout the meteorological community abreast of changes made to the National Meteorological Center (NMC) operational global analysis procedures. The first such report (Dey, et.al., 1985) covered the year 1984. This one is devoted to 1985 and 1986. The basis for all NMC operational global analyses remains the optimum interpolation procedure described in Dey and Morone (1985). Although few changes were made to the system during 1985, significant modifications were implemented in 1986. We hope this description will prove useful to users of the NMC global analyses.

Section II describes briefly the various global analyses run operationally at NMC. Section III reviews the changes we made to our operational analysis procedures during 1985 and 1986. Problems that significantly affected our global analyses during these two years are described in the final section.

II. OVERVIEW OF NMC OPERATIONAL GLOBAL ANALYSES

Three distinct global analyses are run at NMC every 12 hours: the ERL -- Early -- analysis (1 + 05 data cutoff), the AAFS -- Aviation Analysis and Forecast System -- analysis (3 + 45 data cutoff), and the GDAS -- Global Data Assimilation System -- analyses (6 + 00 cutoff for data centered on 0000 GMT, 8 + 30 cutoff for data centered on 1200 GMT, and 9 + 30 cutoff for data centered on 0600 GMT and 1800 GMT). The ERL analysis provides initial conditions for a 48-hour barotropic forecast. The AAFS analysis is used to initiate a 72-hour global forecast designed to provide guidance for the aviation community. The GDAS analyses provide initial conditions for the 6-hour global forecasts that represent the forecast part of the GDAS. The 6-hour global forecasts are used as the first guess for all NMC operational analyses, both regional and global. In addition, the 0000 GMT GDAS analysis provides initial conditions for a 10-day medium-range forecast (MRF) model integration.

III. CHANGES MADE DURING 1985 AND 1986

A. Implementation of 1200 GMT, February 20, 1985 (AAFS, GDAS)

Two changes to the global relative humidity analysis were made at this time. In the global OI analysis, the shape of the correlation function used for the relative humidity analysis is a function of the analyzed wind field. A temporary wind field is used for this purpose, constructed by adding the analyzed wind corrections to the first guess wind values. In order to do this, a transformation from latitude/longitude to polar stereographic coordinates is necessary poleward of 70°. In the first change in this implementation, an error was corrected in the coordinate transformation. Furthermore, if no data are available for the wind analysis at a given gridpoint, calm winds had been assumed for the purpose of constructing the relative humidity correlation function. In the second change made at this time, the first guess wind components were used instead.

B. Implementation of 1200 GMT, March 8, 1986 (AAFS, GDAS)

Before the global OI analysis begins, the TIROS sounding data have been anchored to the first guess 1000 mb height field in order to perform the gross error check. After the 1000 mb analysis is complete, the TIROS soundings are reanchored to the 1000 mb height analysis prior to being made available for use in the height and wind analyses above 1000 mb. A coding mistake in the reanchoring procedure was corrected in this implementation.

C. Implementation of 1200 GMT, May 28, 1986 (GDAS)

Major changes were made to the GDAS at this time, affecting virtually every computer program used in the system. The changes can be subdivided into two general categories -- changes to the analysis procedures themselves and changes to the global forecast model. The latter changes are included in this report because they were so substantial and because the quality of the prediction model used in the GDAS is of crucial importance to the performance of the total system.

1. Changes to Analysis Procedures

Changes were made to the analysis procedures not only to improve the performance of the analysis itself, but also to permit incorporation of a higher resolution and more sophisticated MRF model. There were basically six changes made at this time.

a. The resolution of the quasi-equal area analysis grid was increased to permit calculation of analyzed corrections at 40-wave rhomboidal trunction without significant error. This necessitated an increase in the number of analysis gridpoints from 3124 to 5740. The approximate spacing of the new analysis grid is 2.25° latitude by 4.5° longitude.

b. The number of observations allowed to influence the calculation of an individual analyzed correction was increased from 20 to 33 (this represents an increase by a factor of approximately 2.5 in the number of unique matrix elements). Furthermore, the 33 observations are chosen by considering all 9 mass/wind correlation functions instead of simply selecting the closest 20 as was done previously.

c. TIROS sounding data over land (above 100 mb) began to be used. This was done by reanchoring all TIROS sounding data over land to the 100 mb height analysis before proceeding with the 70 mb and 50 mb height and wind analyses.

d. A direct solution of the matrix problems by Cholesky decomposition replaced the iterative method of conjugate gradients. Use of the direct solution forced us to be more cautious in the formulation of the matrix problems. In particular, several categories of data (TIROS, aircraft, and surface ships) are pre-screened. When two observations of the same type are within a distance equivalent to the 1° latitude, the more asynoptic report is rejected. This is viewed as a temporary expedient until an appropriate super observation formulation can be developed.

e. Changes a-c represented an increase of a factor of 5 in the work to be performed by the analysis. In order to keep computer time down, the formulation and solution of the analysis matrix problems were highly vectorized. The result was the new program required no more computer time than the old one.

f. A new version of the post-processor was implemented that gave improved balance for heights and winds, especially at 50 mb. This post-processor assumed that temperature was constant inside each sigma layer and then derived heights at the same vertical locations as the model winds. Then heights and winds, valid at identical locations, could consistently be interpolated from sigma to pressure linearly with the logarithm of pressure.

2. Changes to the MRF Model

The global spectral prediction model is a crucial component of the GDAS. In this implementation, the latest model used to make medium-range forecasts (the MRF model) was used in the GDAS for the first time. The MRF model improves upon the global spectral model used previously in the GDAS in a number of significant ways. The horizontal resolution is increased from 30 to 40 wave rhomboidal truncation, and the vertical resolution is increased from 12 equal to 18 unequal sigma layers. In addition, the GFDL "E2" level physical parameterization (Miyakoda and Sirutis, 1986) replaced the much less sophisticated procedures used previously. It is beyond the scope of this report to discuss the improvements made to the global spectral model at greater length. However, the models are briefly compared in Table 1 (new model) and Table 2 (previous model).

An important benefit of the new system is that the same global prediction model used to make the medium-range forecasts is now used in the GDAS. This allows the same sigma coordinate analysis used to initiate the 0000 GMT 6-hour GDAS prediction to be used to initiate the medium-range forecasts as well. Previously, a different (and less satisfactory) procedure was used.

D. Implementation of 1200 GMT, Sepember 10, 1986 (GDAS)

Three changes were made at this time in response to the upper level problem described in the next section. Although the changes corrected the problem, we believe further improvements are both possible and desirable.

1. The method of calculating mandatory pressure level heights from sigma surfaces was revised once again. In this revision, the heights of the sigma interfaces are first calculated. Then a simple hydrostatic equation is integrated from the sigma surface just below the mandatory pressure level in question, assuming the temperature remains constant throughout the sigma layer.

2. The method of interpolating the analyzed corrections to the first guess from pressure to sigma was modified. Details of the modified procedure can be found in a Medium-Range Modeling Branch Note available upon request.

3. The MRF model was altered (only when used in the GDAS) by adding a diffusion term to drive the temperatures in sigma layers 17 and 18 toward climatology.

E. Implementation of 1200 GMT, November 17, 1986 (GDAS)

In this implementation, the program that interpolated from sigma to pressure (the post processor) was changed to the version used with the medium-range forecasts. This was an effort to consolidate computer programs, and no significant meteorological changes were involved (or so we thought - see next section).

F. Implementation of 1200 GMT, November 17, 1986 (AAFS)

This was a major change. In it, the global OI analysis used in the GDAS replaced the AAFS OI analysis and the MRF model replaced the 40-wave, 12 layer global spectral model that had been used in the the AAFS. This implementation was therefore much like item C above, but incorporated items D and E as well.

IV. PROBLEMS ENCOUNTERED DURING 1985 AND 1986

In any system as complex as the GDAS and AAFS, it is difficult to avoid some problems. The following describes four such problems. This list is not exhaustive, but it covers those most likely to affect users of the NMC global analyses. It should be noted that the first and last problems listed below affected only pressure level temperature fields, and therefore did not enter into any forecast.

A. Noisy 1000 mb Temperature Fields

The analyzed 1000 mb temperature fields over oceanic areas were noisy from March 22, 1984, when an error was introduced, until the implementation of March 8, 1986, when it was corrected. The problem went undetected for many months because the analyzed 1000 mb temperature field is one that is not used in the GDAS.

B. Satellite Data Problems

A number of problems have occurred with the quality of the TIROS sounding data during the past year. The problems were especially numerous and severe following a major NESDIS software change in the middle of April 1986. In response, all NOAA-6 data were finally withheld from all operational analyses beginning at 1200 GMT on May 30. The data were re-introduced at 1200 GMT on August 4. However, poor NOAA-6 data quality may well have degraded the Southern Hemisphere Analyses from the middle of April until they were removed at the end of May. This particular episode revealed deficiencies in the ability of NMC to detect and therefore respond to problems affecting entire types of data. A second period of problems began at the beginning of November. In response, we withheld all NOAA-6 data and all NOAA-9 data north of 20°S beginning at 1200 GMT on November 7 and ending at 1200 GMT on November 24. Some degradation in the quality of the analyses is likely during this period.

C. Upper Level Problems

The introduction of the revised post-processor on May 28 caused serious problems with the quality of temperature analyses and 6-hour forecasts. The problem arose because the method of interpolating the first guess from sigma to pressure introduced on May 28 proved to be inconsistent with the procedure used to interpolate the analyzed corrections to the first guess from pressure back to sigma. The inconsistency led to a situation in which the first guess in sigma layer 17 was too cold, but the post-processed heights implied thickness temperatures that were too warm. The 70 mb temperatures derived from the analyzed height fields were most strongly affected. The problem persisted until September 10, when the inconsistency was corrected.

D. Anomalous Underground Temperatures

The only meteorological difference between the post-processor introduced into the GDAS and AAFS on November 17, 1986 and the version it replaced was the method of calculating underground temperatures. The new procedure proved to produce anomalous temperatures when the mandatory pressure level is underground. The problem persisted from November 17 until the end of the year.

References

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Table 1. Characteristics of the New GDAS Global Prediction Model

Resolution:	Global spectral rhomboidal-40 truncation. Eighteen (18) unequally spaced layers.
Orography:	Silhouette mountains (enhanced, without smoothing) (Mesinger/Mintz).
Cumulus Convection:	Deep convection (Kuo/Anthes). Shallow convection (Tiedike).
Large Scale Condensation and Evaporation of Rain:	100% saturation criterion. Modified Kessler formulation.
Air-Surface Interaction:	Analysis of SST (fixed during forecast). Predicted land temperature and moisture.
Diffusion:	Horizontal -- quasi-isobaric, biharmonic, for u, v, t, and q, but not pstar. Vertical -- stability dependent for temperature, momentum, and humidity.
Radiation:	Short-wave -- Lacis and Hansen. Long-wave -- Fels and Schwartzkopf. 12 hourly update, three layers of clouds zonally averaged climatological.
Surface Parameters:	
Roughness:	Vegetation dependent over land. Stress dependent over oceans.
Albedo:	Monthly mean modified by snow cover.
Soil Moisture:	Monthly climate interactive with forecast precipitation and evaporation.
Snow Depth/Cover:	Monthly climate interactive with forecast snow and evaporation.
Sea Ice:	Monthly climate, fixed during integration.

Table 2. Characteristics of the Old GDAS Global Prediction Model

Resolution:	Global spectral rhomboidal-30 truncation. Twelve (12) unequally spaced layers.
Orography:	Mean (enhanced, without smoothing) mountains.
Cumulus Convection:	Deep convection, latent heat released only in moisture bearing layers. No shallow convection.
Large Scale Condensation and Evaporation of Rain:	100% saturation criterion. No Kessler formulation.
Air-Surface Interaction:	Analyzed SST, no heat or vapor exchange over land.
Diffusion:	Horizontal -- Del 4 in sigma Vertical -- No vertical diffusion. Surface exchange of temperature and moisture over oceans. Dry adiabatic adjustment for temperature.
Radiation:	None.
Surface Parameters:	Cressman drag coefficient.