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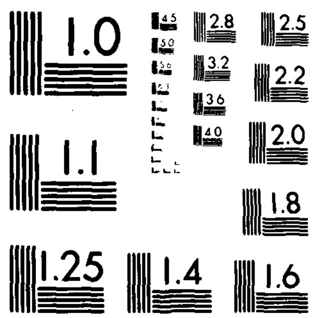

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THE AFGWC AUTOMATED ANALYSIS/FORECAST MODEL SYSTEM

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BY

MAJ TERRY C. TARBELL

CAPT JAMES E. HOKE

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DECEMBER 1979

UNITED STATES AIR FORCE
AIR WEATHER SERVICE (MAC)
AIR FORCE GLOBAL WEATHER CENTRAL
OFFUTT AFB NE 68113

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Ronald L. Lininger

RONALD L. LININGER, Lt Colonel, USAF
Reviewing Official

FOR THE COMMANDER

Robert C. Sabin

ROBERT C. SABIN, Lt Colonel, USAF
Chief, Technical Services Division

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This technical note describes the automated analysis/forecast model system that currently exists at the Air Force Global Weather Central (AFGWC). It emphasizes the interrelation and cycling of the various models in the production cycle, and only addresses the analysis/forecast models that are the primary meteorological data-base builders. Therefore, most applications programs that access the data bases are not discussed.

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PREFACE

This Technical Note (TN) describes the automated analysis/forecast model system that currently exists at the Air Force Global Weather Central (AFGWC). The emphasis will be on the interrelation and cycling of the various analysis/forecast models in the production cycle. This description of the automated analysis/forecast system was written for managers, programmers, computer operations personnel, users of the ultimate products, and the meteorological community at large. This TN will only address analysis/forecast models that are the primary meteorological data-base builders. Most applications programs that access the data bases are therefore not included.

The authors are indebted to many people. Thanks are due to the dedicated people who together built the automated analysis/forecast system. Special thanks are due to:

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Major Terry C. Tarbell
Captain James E. Hoke
31 December 1979

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1. INTRODUCTION

The AFGWC analysis/forecast system has evolved over the past 20 years. The system in its present form is large and complex. Some of the factors which have led to its present form are:

a. AFGWC's worldwide mission in support of numerous Department of Defense (DOD) and other customers.

b. The continual development of meteorological analysis and forecast models and techniques at AFGWC and other locations in the meteorological community.

c. The specific computer hardware at AFGWC. The major computer hardware components are 3 Univac 1110s and 2 Univac 1100/81s.

d. The continual technological development of systems for taking meteorological observations, especially meteorological satellites.

e. A greater availability of data in the Northern Hemisphere (NH) than in the Southern Hemisphere (SH). Also, more operational requirements exist in the NH than in the SH. Therefore, more emphasis is placed on the NH.

f. More data are available during the ontime (00Z, 12Z) cycles than the offtime (06Z, 18Z) cycles and thus the emphasis is on the ontime cycle.

In view of the above reasons, no master plan addressing the entire automated system was possible when the system was initiated. Even today the automated analysis/forecast system is constantly undergoing change. These changes are driven by operational requirements. The operational requirements are stated by internal AFGWC data-base users and by the numerous external customers supported by AFGWC.

There are three general classes of meteorological analysis/forecast models that are meteorological data-base builders at AFGWC. These three classes are cloud models, conventional models, and ionospheric models. Cloud models are those models whose primary objective is the analysis/forecast of clouds. For the purpose of this TN, we define conventional models as those tropospheric and stratospheric models that are non-cloud models For example, conventional models analyze/forecast winds, heights, and temperatures. Ionospheric models will not be discussed in this TN. Therefore, the AFGWC automated analysis/forecast model system as described here is composed of the conventional and cloud models.

1.1 Cycles.

Before a discussion of analysis and forecast models and how these models are linked in an automated system that is called a production cycle, it is useful to understand the concept of a cycle. A cycle is a period of time during which a given sequence of models is run. This sequence of models is repeated on the next cycle. A cycle always begins at a data time (that is, on the hour). The cycles used are 3, 6, and 12 h in length. These three cycles are combined to constitute the AFGWC production cycle.

The two 12-h cycles are the 12-h periods beginning at 00Z and 12Z. Each of these cycles is termed a primary models cycle or simply a cycle. The 12-h cycles begin at 00Z and 12Z because more conventional observations are taken at those times than at any other times. For a given day, the two cycles are referred to as the 00Z cycle and the 12Z cycle.

A 12-h cycle can be further divided into two 6-h cycles. These 6-h cycles are the ontime cycles beginning at 00Z and 12Z and the offtime cycles beginning at 06Z and 18Z. More conventional data are available for the ontime cycle than the offtime cycle. (This fact can influence the forecast skills of the models that are run on each cycle.)

The cloud analysis and forecast models are run every three hours. Hence, a 12-h cycle can be subdivided into four three-hour "neph" cycles beginning at the 00Z, 03Z, 06Z, and 09Z data times for the 00Z cycle and the 12Z, 15Z, 18Z, and 21Z data times for the 12Z cycle.

2. THE AFGWC GRID SYSTEM

Because the model grids used at AFGWC are described in detail by Hayes, Hoke, and Irvine (1979), only a brief discussion will be presented here. For the NH and SH, a polar stereographic projection true at 60^{0} latitude is overlaid by a grid. The grid increment (Δx), distance between adjacent grid points, is 381 km (about 200 nm) at 60^{0} latitude. Since the corners of the grid are not used, the 47 x 51 grid becomes an octagon rather than a rectangle. The edges of the octagon lie between 9^{0} and 18^{0} latitude. This grid is similar to the one used at the National Meteorological Center (NMC). A significant percentage of the world's land mass is within the NH octagon. On the other hand, oceans cover about 90 percent of the SH octagon. Because of this more conventional data are available in the Northern Hemisphere. The sparsity of conventional data in the Southern Hemisphere can lead to difficulties in the Southern Hemisphere analyses.

In the Tropics (TR) AFGWC uses a Mercator projection with a grid increment of 577 km (about 300 nm) at the equator and 445 km (about 255 nm) at 30^{0} latitude. This 19 x 72 grid, centered on the equator, extends between about 41^{0}S and 41^{0}N. The fact that AFGWC uses different grids for different portions of the globe has contributed to the complexity of the automated analysis/forecast model system.

The NH and SH grids with 381-km grid increment are referred to as whole-mesh grids. Alternate designations include coarse-mesh grid and 1 bedient grid. Finer-mesh grids are defined relative to the whole-mesh grids. For example, FIVLYR, a cloud forecast model, utilizes a half-mesh grid (190.5-km grid increment). 3DNEPH, a cloud analysis model, employs an eighth-mesh grid (about 48-km grid increment).

AFGWC also runs models over three half-mesh "window" grids that lie within the NH octagon. These windows cover most of North America (U.S. window), Europe and western Asia (European window), and eastern Asia (Asian window).

3. AUTOMATED DATA PROCESSING AT AFGWC

Before the analysis/forecast models can be executed, meteorological data must be supplied. Although this TN is concerned with how the incoming data are processed after they are validated and stored in the AFGWC data base, it is appropriate to review briefly how the data reach the data base from the outside world.

Data are primarily conveyed to AFGWC by three means:

a. the Automated Weather Network (AWN),

b. communications satellites (COMSAT), and

c. land lines.

The AWN is a worldwide high-speed communications system through which most of AFGWC's conventional data and some of AFGWC's satellite data arrive. The conventional data are non-satellite data; that is, surface reports, rawinsondes (RAOBs), aircraft reports (AIREPs), etc. COMSAT relays data from meteorological satellites such as Defense Meteorological Satellite Program (DMSP) satellites, National Oceanographic and Atmospheric Administration (NOAA) satellites, and Geostationary Operational Environmental (GOES) satellites. Land lines link AFGWC with other weather centers, such as the Navy's Fleet Numerical Oceanographic Center (FNOC), Monterey, CA, and the National Severe Storm Forecast Center, Kansas City, MO.

When conventional data arrive at AFGWC, the computer program known as RTWX (Real-time Weather) identifies and decodes the data. RTWX stores the raw data in the "batch" file. Periodically, the raw data in this file are "batched"; that is, a program reads the data from the batch file, validates (performs a gross error check on) the data, and stores the validated data in the AFGWC "regions" data base. On the average, surface data are batched every half hour while upper-air data are batched every hour. An AFGWC region is a portion of the globe. For example, AFGWC region 43 is bounded by $30^{o}N$, $40^{o}N$, $95^{o}W$, and $109^{o}W$. The analysis models then retrieve data from the appropriate regions data base.

Other information also available to the analysis/forecast models include terrain elevations and climatological data stratified by month and standard pressure level.

4. AFGWC ANALYSIS MODELS

4.1 Subjective versus objective analysis.

A subjective analysis is an analysis done manually by a forecaster. When a computer is programmed to do an analysis automatically, the result is called an objective analysis. Because this TN addresses computer models, the primary concern here is objective analysis.

Objective analysis consists of determining values of meteorological parameters for a set of uniformly spaced points from meteorological observations taken at irregularly spaced points. The set is called a grid. Grids are usually composed of uniformly spaced points because this greatly simplifies the equations used by the analysis/forecast models.

For numerical analysis and forecast models, it is important to emphasize that the meteorological variables are defined only at the individual grid points. In the real atmosphere, each variable (for example, temperature) has continuous values at every point in time and space. In a numerical model, a variable simply is not defined between grid points, although the grid-point value is assumed to represent the variable in the vicinity of the point. Meteorological features smaller than $4\Delta x$ cannot adequately be analyzed or forecast on a grid. Therefore, for a 381-km grid increment, features smaller than 1600 km in diameter are not forecast accurately.

4.2 Objective analysis models.

It is instructive to consider how objective analysis is done. For example, what is done in an objective analysis when there are conflicting observations near the same grid point? Alternatively, what logic is followed when there are no observations near a grid point? Meteorologists have rules of thumb on how to deal with these situations in their subjective analyses. An objective analysis model is basically the use of these rules of thumb applied in a predetermined and consistent manner.

The first objective analysis method used at AFGWC was the successive correction technique. This method was developed by Cressman (1959) and later modified by others. First, a guess is made for a variable at each grid point. The guess is then corrected based on nearby observations. The nearer an observation is to a grid point, the more influence that observation has on the final value of the variable at the grid point. If there are no observations near a given grid point, the first-guess value for that grid point remains unchanged. Therefore, it is important to begin with a good first guess. For most of AFGWC's analysis models, the first guess is a 6-h or 12-h forecast from one or more of the forecast models. In some cases the first guess is the previous analysis.

An analysis model usually performs an analysis in several "scans". A scan consists of one pass through the data. The first scan uses the first-guess field as its first guess and updates that first guess with data. The resulting field at the completion of the first scan becomes the first-guess field for the next scan. The final analysis is the field produced by the last scan. All or any portion of the observations may be considered by each scan.

During each scan, each observation considered is compared to the first-guess value at that location. If the difference between the observed and first-guess values exceeds a specified amount, then either the observed value or the first-guess value (usually the former) is disregarded or thrown out. Therefore, the specified amount is referred to as the "throwout criterion". Throwout criteria are usually established based on past experience and may vary with meteorological variable, scan number, season, and height of the level being analyzed.

4.3 Current analysis models

The current analysis models used at AFGWC are given in Table 1. For each model, Table 1 contains the runstream names that execute that model, the purpose of each runstream, whether it is a primary or a backup runstream, the time the runstream is scheduled (primary runstreams only), the grid mesh on which the model provides an analysis, the computer core size in thousands of words, the runstream's execution length in wall time, the levels at which variables are analyzed, and the variables analyzed. Note that a runstream is a set of control statements that execute the model. Wall time is the average length of time a runstream executes from the time it is started until it is finished. The wall time depends on such factors as the number of I/Os (input/output operations) performed by the runstream, the runstream priority, the other programs running, the computer system utilized (Univac 1110 or Univac 1100/81, for example), and the number of processors the computer has available. For each model, a brief description is given.

4.3.1 FMANAL - Fine-mesh Upper-air Analysis Model. FMANAL is used to

Table 1 AFGWC Analysis Models

Model	Primary or Backup	Grid Mesh	Runstream	Runstream Purpose	Scheduled Runtime (Z) (primary only)	Wall Time (min)	Core Size (K words)	Levels (mb)	Meteorological Variables Analyzed
FMANAL	Primary	1/2	ASFMUP	Ontime fine-mesh upper-air analysis, Asian window	0325 1525	10	58	850-100	u,v,D,T,$T-T_d$
	Primary	"	ASFMU7	Offtime version of ASFMUP	0848 2048	8	"	"	"
	Primary	"	EUFMUP	Ontime fine-mesh upper-air analysis, European window	0259 1459	"	"	"	"
	Primary	"	EUFMU7	Offtime version of EUFMUP	0833 2033	6	"	"	"
	Primary	"	FMUPR	Ontime fine-mesh upper-air analysis, U.S. window	0115 1315	5	"	"	"
	Primary	"	FMUPRL	Same as FMUPR except run later in ontime cycle	0210 1410	"	"	"	"
HIANAL	Primary	whole	MULTN2	Ontime NH upper-air analysis above 100 mb	0450 1650	12	46	70-10	u,v,D,T
	Primary	"	MULTN4	Ontime update of MULTN2	0817 2017	15	"	"	"
	Backup	"	SHMLTØ	Ontime SH upper-air analysis above 100 mb (1st guess regressed from 100 mb analysis)		10	"	"	"
	Primary	"	SHMLT1	Same as SHMLTØ except 1st guess built hydrostatically from 100 mb analysis	0705 1905	7	"	"	"

Table 1. Continued

Model	Primary or Backup	Grid Mesh	Runstream	Runstream Purpose	Scheduled Runtime (Z) (primary only)	Wall Time (min)	Core Size (K words)	Levels (mb)	Meteorological Variables Analyzed
HUFANL	Primary	whole	HUFGES	Formats 1st guess for HUFANL	0020 1220	22	52	sfc-100	u,v,D,T
	Primary	"	HUFANL	Provides global analysis from first-guess, observations, and bogus; stores NH fields *	0305 1505	26	53	"	"
	Primary	"	HUFALU	Provides global analysis from HUFANL analysis, observations, and bogus *	0606 1806	30	"	"	"

* Also executes TROP for a tropopause analysis and SFC and MULTAN for a $T\text{-}T_d$ analysis for the Northern Hemisphere.

Model	Primary or Backup	Grid Mesh	Runstream	Runstream Purpose	Scheduled Runtime (Z) (primary only)	Wall Time (min)	Core Size (K words)	Levels (mb)	Meteorological Variables Analyzed
MULTAN	Backup	whole	MULTN1	Ontime NH upper-air analysis		15	51	850-100	$u,v,D,T,T\text{-}T_d$
	Backup	"	MLTN1A	Update of MULTN1		5	"	"	"
	Primary	"	MULTN3	Offtime NH upper-air analysis	0925 2125	15	"	"	"
	Backup	"	SHMLTN	Ontime SH upper-air analysis		"	"	"	"
	Backup	"	SHMLTU	Update of SHMLTN		5	"	"	"
	Primary	"	SHMLT7	Offtime SH upper-air analysis	1110 2310	19	"	"	"
PREWAT	Primary	whole	PREWAT	Ontime NH precipitable water analysis	0335 1535	7	"	6 layers between sfc, 850, 700, 500, 400, 300, 100	precipitable water

Table 1. Continued

Model	Primary or Backup	Grid Mesh	Runstream	Runstream Purpose	Scheduled Runtime (Z) (primary only)	Wall Time (min)	Core Size (K words)	Levels (mb)	Meteorological Variables Analyzed
SFC	Primary	1/2	ASFMSF	Ontime Asian window fine-mesh surface analysis	0320 1520	10	54	1000, sfc	$u,v,D,T,T-T_d$ SLP
	Primary	"	ASFMS7	Offtime version of ASFMSF	0839 2039	"	"	"	"
	Primary	"	EUFMSF	Ontime European window fine-mesh surface analysis	0149 1349	"	"	"	"
	Primary	"	EUFMS7	Offtime version of EUFMSF	0820 2020	13	"	"	"
	Primary	"	FMSFC	Ontime U.S. window fine-mesh surface analysis	0109 1309	6	"	"	"
	Backup	whole	SFANAL	Ontime NH surface analysis		10	52	"	"
	Primary	"	SFAN7Ø	Offtime version of SFCANL	0820 2020	6	"	"	"
	Backup	"	SHSFC	Ontime SH surface analysis		4	"	"	"
	Primary	"	SHSFC7	Offtime version of SHSFC	1049 2249	"	"	"	"
SFC, MULTAN, TROPSF, and TROPUA	Primary	whole	TSHDEW	TR and SH ontime moisture analysis	0705 1905	7	52	sfc-100	$T-T_d$

Table 1. Continued

Model	Primary or Backup	Grid Mesh	Runstream	Runstream Purpose	Scheduled Runtime (Z) (primary only)	Wall Time (min)	Core Size (K words)	Levels (mb)	Meteorological Variables Analyzed
SFTMP	Primary	1/8	SFTMP	NH surface temperature analysis	0126 + every 3h thereafter	7	66	sfc	T
	Primary	"	SFTMP,40	SH surface temperature analysis	0225 + every 3h thereafter	"	"	"	"
SNODEP	Primary	"	SNODEP	Global snow cover analysis	1426	10	84	"	Snow depth, age
TROP	Primary	whole	SHTROP	Ontime SH tropopause analysis	0740 1940	3	52	tropopause	tropopause pressure, height, and temperature
	Backup	"	TROP	NH ontime tropopause analysis and forecast through 48 h		2	"	"	"
	Backup	"	TROP72	Extension of TROP through 72 h		"	"	"	"
	Primary	"	TTROP	Ontime TR tropopause analysis	0712 1912	1	18	"	"
	Primary	"	TTROP7	Offtime version of TTROP	1145 2345	1	16	"	"
TROPSF	Backup	whole	TRPSFC	Ontime TR surface analysis		2	44	sfc, 1000	u,v,D,T,T-T_d,SLP 1000 mb: D,T
	Primary	"	TRPSF7	Offtime version of TRPSFC	1137 2337	"	"	"	"
TROPUA	Backup	whole	TWAONT	Ontime TR upper-air analysis		10	56	850-100	u,v,D,T,T-T_d,400 and below

Table 1. Continued

Model	Primary or Backup	Grid Mesh	Runstream	Runstream Purpose	Scheduled Runtime (Z) (primary only)	Wall Time (min)	Core Size (K words)	Levels (mb)	Meteorological Variables Analyzed
TROPUA	Primary	whole	TWA7	Offtime TR upper-air analysis	1139 2339	4	56	850-100	u,v,D,T,T-T_d, 400 and below
TWA2	Primary	whole	TWAHI	Ontime TR upper-air analysis above 100 mb	0636 1836	27	65	70-10	u,v,D,T
	Backup	"	TWA2	Version of TWAHI that uses climatology as the first guess		28	"	"	"
23DTMP	Primary	1/8	23DTMP	Sea surface temperature analysis for 3DNEPH	0411 1611	2	44	sfc	T
3DNEPH	Primary	1/8	3DNEPH	NH nephanalysis	0128 + every 3 h thereafter	35-50	72	15 levels from sfc to 55000 ft	total cloud cover (%), min bases, max tops, cloud type, present weather
	Primary	"	SH3DNF	SH nephanalysis	0230 + every 3 h thereafter	38	63	"	"
	Primary	"	1SPTNF	Processing of first quarter orbit of DMSP data	satellite dependent	12	72	"	"
	Primary	"	2SPTNF	Version of 1SPTNF for second quarter orbit	"	"	"	"	"
	Primary	"	3SPTNF	Version of 1SPTNF for third quarter orbit	"	"	"	"	"
	Primary	"	4SPTNF	Version of 1SPTNF for fourth quarter orbit	"	"	"	"	"

provide half-mesh analyses over the Asian, European, and U.S. windows. This model analyzes height (D value), wind (u,v), temperature (T), and dewpoint depression ($T-T_d$) for the nine mandatory levels from 850 to 100 mb (that is, 850, 700, 500, 400, 300, 250, 200, 150, and 100mb). Fleming (1969) described the application of the Barnes (1964) successive correction technique, which is used in this model. In the Barnes technique, successive corrections are applied to a first-guess field using a variable scan radius. The more dense the coverage, the smaller the effective scan radius.

The first-guess fields are derived from forecasts, previous analyses, climatology, or some combination of those three fields. The first-guess 850-mb and 700-mb heights and temperatures, for example, are derived from forecast fields, whereas the 500-mb and 300-mb heights and temperatures are derived hydrostatically from the 700-mb first guess fields. Forecast dewpoint spreads are used for the first guess, and the first-guess winds are derived from first-guess heights using the geostrophic and gradient wind equations.

4.3.2 HIANAL - High-level Analysis Model. HIANAL analyzes heights, winds, and temperatures above 100 mb. It is a Cressman-type model similar to MULTAN, an analysis model that will be described in a later section. HIANAL analyzes the 70-, 50-, 30-, 20-, and 10-mb levels by building a first guess from persistence and the 100-mb level. Because there are large areas above 100 mb where no observations are taken, HIANAL uses regression equations based on latitudinal and seasonal climatology. These equations are given by Moreno (1973).

4.3.3 HUFANL - Hough Global Spectral Analysis. The HUFANL model was developed by Flattery (1971) at NMC. In 1975 the HUFANL model became the primary ontime analysis model at AFGWC. The model is designed to provide global analyses of winds, heights, and temperatures at mandatory levels from the surface to 100 mb.

The first-guess fields for the HUFANL model are produced by HUFGES. These fields are the 12-h forecasts from the previous ontime cycle for the NH and SH and the previous offtime TR analyses. Climatology is also input in the SH to provide a better first guess in the data-sparse oceanic areas south of $20^{o}S$. When AFGWC Forecasting Services Division forecasters determine that the first-guess height field is not satisfactory, they can enter bogus data before the HUFANL model is executed. Bogus data are usually entered only at typical jet aircraft flight levels and over data-sparse areas such as oceans.

In the HUFANL model, first-guess fields are combined with all available observations (including bogus data) in a global spectral analysis based on Hough functions, sines, cosines, and empirically derived orthogonal functions. A least-squares technique is used in which the square of the global mean absolute difference between the analysis and observations is minimized. The winds and heights are balanced to some degree during the analysis. In this model the winds affect the height analysis and the heights affect the wind analysis.

Like most analysis models, the HUFANL model uses data throwout criteria. Unlike most analysis models, however, these throwout criteria are related to the mean difference between the analyzed and observed value that a given variable has at a given level and are modified (made more stringent) with each successive scan. Also, data thrown out on one scan can be incorporated in the analysis on any successive scan.

For several reasons, the HUFANL model is executed twice for each ontime cycle. The first execution (runstream HUFANL) is primarily for a NH analysis. The second execution (runstream HUFALU) is primarily for the TR and SH. The runstream HUFANL is run at T+0305*. Eight scans through the data are made and, even though the entire globe is analyzed, only the NH fields are stored into the data base at this time. This procedure reflects the fact that a significant portion of the upper-air data from the TR and SH has not arrived at AFGWC by T+0305*. During the earlier scans, the large-scale circulation features are analyzed. Smaller-scale features are incorporated during later scans.

At T+0606*, an update to runstream HUFANL, called HUFALU, is run to continue the ontime analysis. HUFALU is the primary ontime TR and SH analysis because, as pointed out earlier, conventional data for the TR and SH are available later in the cycle than NH data. HUFALU also updates the NH analysis that was first computed by runstream HUFANL. Six scans are made during HUFALU. The first three incorporate bogus data only. The last three combine the bogus data with all other available data.

The complete HUFANL model sequence (runstreams HUFGES, HUFANL, and HUFALU) forms the backbone of the conventional model analysis/forecast system.

*T = 00Z or 12Z.

4.3.4 MULTAN - Multi-level Analysis Model. MULTAN is an objective analysis model based on the Cressman (1959) scan technique. This model analyzes wind, temperature, and height (D-value) at mandatory levels from 850 mb to 100 mb on a whole-mesh grid. Dewpoint depression is analyzed from 850 mb to 400 mb. MULTAN is the primary analysis model for the offtime cycle and the backup analysis model for the ontime cycle. MULTAN derives its first-guess fields from previous analyses, forecasts, climatology, or some combination of those fields. Usually, the first-guess temperatures and D-values are taken from forecast D-values. Then, the first-guess winds are derived using the geostrophic and gradient wind equations from the final, analyzed D-value fields. The first-guess dewpoint depressions are produced by the FIVLYR cloud forecast model.

MULTAN uses two to five scans. The throwout criteria are made more stringent with each successive scan. When data throw criteria are applied, the first guess is usually assumed correct. An option exists that specifies whether all or any specific part of the observed data for a station must be considered by the analysis. That is, the data become exempt from throwout criteria under this option. For example, this feature might be used for an isolated observation. In this case, the observation is considered correct and not the first guess.

After the final MULTAN scan, a weak smoother is applied to the analyzed fields. Additionally, horizontal wind shear is checked, as the analysis has a tendency to produce unrealistic anticyclonic shears south of major jetstreams in data-sparse regions.

4.3.5 PREWAT - Precipitable Water Analysis Model. PREWAT analyzes precipitable water for six layers. The first five layers are between the six mandatory pressure levels from 1000 mb to 300 mb and the top layer is between 300 mb and 100 mb.

Analyzed temperature and dewpoint depression fields are used as the first guess, which in turn is modified by soundings. Climatology is incorporated into the top layer where dewpoint depression is usually not reported. Finally, the precipitable water is summed over all six layers.

4.3.6 SFC - Surface Analysis Model. SFC provides whole-mesh surface analyses of pressure, temperature, and dewpoint depression and 1000-mb analyses of D-value and winds.

The first-guess fields used by SFC are usually 6-h forecasts. However, a 12-h forecast or previous 6-h old analysis may also be used. SFC uses a modified Barnes (1964) technique in which the maximum scan radius is $5\Delta x$ in data-sparse regions.

The throw criteria used by SFC are derived from global and local mean deviations for each variable. A total of three scans are used. After the last scan, a 9-point smoother removes features of wavelength $2\Delta x$ from the analyses. Finally, the 1000-mb D-values are calculated from the surface pressure and temperature fields.

4.3.7 TROP - Tropopause Analysis Model. TROP uses upper-air data to analyze each temperature profile for the tropopause level. If no level matching the definition is found, the default values 70 mb, 18440 m, and $-80^{\circ}C$ are used for the tropopause pressure, height, and temperature, respectively.

TROP analyzes temperature and potential temperature in three scans with the scan radius decreasing from $4\Delta x$ to $2\Delta x$. Then, the tropopause pressure is derived using Poisson's equation.

4.3.8 TROPSF - Tropical Surface Analysis Model. TROPSF is similar to SFC except that it is designed to analyze variables on the tropical grid. The model is decribed by Brown (1973). TROPSF employs the modified Barnes (1964) technique. However, the number of observations that can be thrown is limited to 30 percent of the available observations.

4.3.9 TROPUA - Tropical Upper-air Analysis Model. TROPUA provides a whole-mesh tropical upper-air analysis as described by Brown (1973). It is similar to MULTAN except it is applied to the tropical grid. TROPUA analyzes from $30^{\circ}N$ to $30^{\circ}S$ and incorporates analysis information from the NH and SH where the NH and SH octagons overlap the tropical grid.

TROPUA uses the Cressman (1959) technique. Winds, temperatures, and D-values are analyzed from 850 to 100 mb and dewpoint depressions from 850 to 400 mb. No attempt is made to determine whether the final wind and height fields are dynamically consistent. Additionally, the scan radii and data throwout criteria are not modified with varying data densities. Three scans are made with scan radii from $3\Delta x$ to $1\Delta x$. Global and local throwout criteria are used. That is, observations are compared with both the local first guess and the global average for that variable and level.

4.3.10 TWA2 - Tropical Wind Analysis Model. TWA2, a version of HIANAL, analyzes winds, temperatures, and D-values for the levels from 70 mb to 10 mb on the tropical grid.

4.3.11 SFTMP - Surface Temperature Analysis Model. SFTMP provides NH and SH eighth-mesh surface temperature analyses for use by 3DNEPH. The model requires a gradient-level temperature forecast from HEMTMP (see Section 5.3.6) and surface observations to produce a surface temperature field. The temperature forecast used by SFTMP is the forecast whose valid time is closest to that of the following 3DNEPH (Section 4.3.14). SFTMP is run every three hours in each hemisphere to produce a temperature analysis and a three-hour forecast of surface temperature. The forecast is based on a local diurnal trend computation that uses observed cloud cover and soil characteristics. Although SFTMP produces analyses and forecasts, it is used primarily as an analysis model.

4.3.12 SNODEP - Snow Depth Analysis Model. SNODEP provides a global eighth-mesh analysis of snow cover. The model runs once a day with the analysis covering the previous 24 h. Inputs include DMSP video brightness data, climatology data for snow and ice, the depth and age of snow from the previous analysis, hourly observations, and bogus data when required.

4.3.13 23DTMP - Sea Surface Temperature Analysis Model. AFGWC receives sea surface temperature data from Fleet Numerical Oceanographic Center, Monterey, CA. 23DTMP formats the data twice daily to the eighth-mesh grid for use by 3DNEPH.

4.3.14 3DNEPH - Three-dimensional Nephanalysis Model. 3DNEPH is the only known operational global cloud analysis model that blends conventional and satellite data. The model has been described by Fye (1978). Visual and infrared (IR) satellite data, surface observations, the surface temperature analysis from SFTMP, pilot reports, and RAOBs are analyzed to provide layered cloud amounts, total cloud cover (in percent), significant weather, minimum cloud bases, maximum cloud tops, and cloud type for low, middle, and high clouds.

3DNEPH employs the finest vertical and horizontal grid resolution used at AFGWC. Each hemisphere is divided into 64 equal squares called "3DNEPH boxes", each about 1600 nm on a side. Each box contains 64 by 64 eighth-mesh grid points corresponding to a horizontal resolution of about 25 nm at 60° latitude. The model is divided into fifteen vertical layers, the lowest six being terrain-following layers between the following heights above ground level (AGL):

surface, 150, 300, 600, 1000, 2000 and 3500 ft AGL. The top nine layers are between the following heights above mean sea level (MSL): 3500, 5000, 6500, 10000, 14000, 18000, 22000, 26000, 35000 and 55000 ft MSL.

The model runs in two modes. The synoptic mode runs every 3 h in both hemispheres and processes all conventional and satellite data valid during the previous 3 h. When satellite data are received over any region, the "sprint" or window analysis model can be initiated to provide an up-to-date analysis over a limited number of 3DNEPH boxes.

5. AFGWC FORECAST MODELS

5.1 Numerical Prediction Models

Numerical prediction models currently in use at AFGWC have varying degrees of sophistication. These computer programs are called models because they "model" the atmosphere using equations assumed to represent atmospheric processes. These equations are invariably nonlinear partial differential equations, which mathematicians have not, in general, been able to solve analytically.

Because no analytic solution is available, an approximate solution is obtained by numerical integration. Given initial and boundary conditions and one or more predictive equations for the variable(s) to be forecast, a "time step" is taken into the future to get forecast value(s) for that time step. The initial conditions are obtained from one or more of the analysis models described in Section 4. Boundary conditions may vary from model to model. For example, the boundaries may be held fixed at the initial values for the entire forecast or may change according to forecasts provided by a model that has forecast for a larger domain. The size of the time step is restricted by several factors such as grid spacing and the specific equations used. This paragraph has described the essence of numerical weather prediction (NWP). Even though NWP is conceptually simple, the specific numerical techniques required can be extremely complex, even for models that are meteorologically unsophisticated.

5.2 Primitive-equation (PE) Models

Most NWP models developed today are baroclinic primitive-equation models, often referred to as PE models. In general, these models produce better forecasts than their forerunners, the so-called filtered and barotropic models. One reason for this is that PE models allow baroclinic and other processes not

not permitted in barotropic models. These additional processes usually require the use of more complex numerical techniques and a smaller time step as well.

5.3 Current Forecast Models

Table 2 contains the same type of information for each forecast model that Table 1 presented for each analysis model (see Section 4.3). A brief description of each forecast model follows.

5.3.1 AWSPE - Air Weather Service Primitive-equation Model. AWSPE is the AFGWC version of the Shuman and Hovermale (1968) 6-layer PE model which became operational at NMC in 1966. AWSPE was implemented at AFGWC in 1975. Unlike the Shuman and Hovermale version, the AWSPE does not contain a moisture variable. This simplification was made primarily so that the model could meet production timelines when run on the available computer hardware. Also, to meet these timelines, a pressure-averaging technique has been incorporated that permits computational stability at double the time step.

AWSPE is a synoptic-scale model with a grid increment of 381 km at $60^{o}N$ (whole mesh). Because of hardware limitations, it is run only for the Northern Hemisphere. Forecasts are made to 72 h for the ontime cycle and to 36 h for the offtime cycle. Also, because of hardware limitations, AWSPE is the highest resolution conventional hemispheric forecast model currently contributing to the meteorological data base at AFGWC.

The AWSPE model has prognostic equations for the horizontal wind components and temperature, a mass conservation equation, and several diagnostic equations. The model has six forecast layers: one planetary boundary layer, three other layers in the troposphere, and two layers in the stratosphere. A seventh layer, existing at the top of the model, is included for numerical rather than physical reasons. AWSPE is formulated in the sigma (normalized pressure) coordinate system. The terrain field has been smoothed to remove terrain features with wavelengths less than $4\Delta x$ as such features would introduce nonphysical anomalies.

Characteristics of the AWSPE are similar to those of other PE models. Because fixed boundary conditions are used on the NH octagon during the forecast, spurious vorticity centers sometimes form near the boundary. Features characterized by short wavelengths tend to move too slowly. In general, the development of new systems is underforecast. One reason for this is the lack of moisture and its associated latent heat release. AWSPE performs best for large-scale, slowly developing systems over land. Conversely, it does poorly for

Table 2. AFGWC Forecast Models

Model	Primary or Backup	Grid Mesh	Runstream Name	Runstream Purpose	Scheduled Runtime (Z) (primary only)	Wall Time (min)	Core Size (K words)	Levels (mb)	Meteorological Variables Analyzed
AWSPE	Primary	whole	AWSPE	Ontime NH forecast to 48 h	0350 1550	20 min/ 12 h forecast	90	sfc-100	u,v,D,T,p_{sfc} p_{trop}
	Primary	"	AWSPE7	Offtime NH forecast to 36 h	0940 2140	"	"	"	"
	Backup	"	AWSPER	Restart AWSPE, AWSPE7, or NHPE72 at a 6-h point		"	"	"	"
	Backup	"	GMRFBU	NMC MRF backup, extends AWSPE to 96 h		"	"	"	"
	Primary	"	NHPE72	Extends AWSPE to 72 h	0535 1735	"	"	"	"
	Primary	"	PE12 PE24 PE36 PE48 PE60 PE72 PE712 PE724 PE736	Stores AWSPE fields in data base every 12 h (712,724,736 indicate offtime runstreams)	Started by an AWSPE runstream	4	43	"	"
BLM	Primary	1/2	BL12HR	12-h U.S. window forecast	0420 1620	14	54	sfc,50 m, 150 m, 300 m, 600 m,900 m, 1200 m,1600 m	u,v,D,T,q,total moisture
	Primary	"	ASBLYR	Asian window forecast to 36 h	0531 1731	31	"	"	"
	Primary	"	EUBLYR	European window forecast to 36 h	0507 1707	31	"	"	"

Table 2. Continued

Model	Primary or Backup	Grid Mesh	Runstream Name	Runstream Purpose	Scheduled Runtime (Z) (primary only)	Wall Time (min)	Core Size (K words)	Levels (mb)	Meteorological Variables Analyzed
BLM	Primary	1/2	USBLYR	U.S. window forecast to 36 h	0507 1707	31	54	See BLM	See BLM
	Primary	whole to 1/2	PEASPG	Interpolates AWSPE fields to window grid boundaries from 1 to 36 h	0457 1657	5	35	850-300	u,v,D,T
	Primary	1/2	LOLVLA	U.S. window analysis run early in cycle	0215 1415	6	57	See BLM	See BLM
SIXLVL	Backup	whole	NH6LVL	Ontime NH 48-h forecast		40	65	850-100	u,v,D,T
	Primary	"	NH6LVU	Ontime NH 12-h forecast	0735 1935	10	"	"	"
	Backup	"	NH6L72	Ontime NH 48-72 h forecast		20	"	"	"
	Backup	"	SIXLVL	Duplicates any SIXLVL runstream depending on option			"	"	"
	Primary	"	SH6LVL	Ontime 48-h forecast for SH	0636 1836	27	"	"	"
	Primary	"	SH6LV7	Offtime 6-h forecast for SH	1129 2329	6	"	"	"
	Primary	"	OLDTR6	Ontime and offtime tropical stream function analysis	0703 1143 1903 2343	2	60	"	vertical velocity; stream function
1MPROG	Backup	"	NH1MPG	Ontime NH 48-h surface forecast		3	45	sfc,1000	sfc: p,T 1000 mb: u,v,D,T
	Primary	"	NH1MPU	Ontime NH 12-h surface forecast	0753 1953	2	"	"	"

Table 2. Continued

Model	Primary or Backup	Grid Mesh	Runstream Name	Runstream Purpose	Scheduled Runtime (Z) (primary only)	Wall Time (min)	Core Size (K words)	Levels (mb)	Meteorological Variables Analyzed
1MPROG	Backup	whole	NH1MP7	Offtime NH 36-h surface forecast		3	45	sfc,1000	sfc: p,T 1000 mb: u,v,D,T
	Backup	whole	NH1M7U	Offtime NH 6-h surface forecast		2	45	sfc,1000	sfc: p,T 1000: u,v,D,T
	Primary	"	SH1MPG	Ontime SH 36-h surface forecast	0703 1903	"	"	"	"
	Primary	"	SH1MP7	Offtime SH 6-h surface forecast	1135 2335	"	"	"	"
FIVLYR	Primary	1/2	NH5LYR	NH 48-h cloud forecast	0203+every 3h thereafter	15-30	67	gradient, 850,700, 500,300	CPS,T,cloud type, $T-T_d$,icing,QPF, total and layered cloud
	Primary	"	SH5LYR	SH 24-h cloud forecast	0008+every 3h thereafter	12	"	"	"
HEMTMP	Primary	1/2	HEMTMP	Reformats global temperature analyses and forecasts to 12 h	0345+every 6h, 0640 + every 6h	1	54	gradient	T
HRCP	Primary	1/8	1HRCP	High-resolution 9-h cloud forecast for a given 3DNEPH box	satellite dependent	20	65	same as 3DNEPH	same as 3DNEPH
	Primary	"	2HRCP	Same as 1HRCP; used to run simultaneously with 1HRCP	"	"	"	"	"
TRONEW	Primary	1/2	TRONEW	24-h TR persistence cloud forecast	0218+about every 3h for NH 0308+every 3h for SH	2	42	low, middle, high	cloud amount, layered and total

small, rapidly developing systems over oceans.

5.3.2 BLM - Boundary Layer Model. The BLM was described by Hadeen (1970). The BLM forecasts winds, temperatures, D-values, and specific humidities to 36 h over the three half-mesh window grids. The model has eight terrain-following vertical levels from the surface to 1600 m above the terrain.

The lateral and vertical boundary conditions for the BLM are obtained by interpolating the whole-mesh AWSPE forecast fields to half mesh. This interpolation is accomplished by the PEASPG runstream listed in Table 2. The BLM has forecast equations for temperature and specific humidity. Forecast equations for the wind components are not used because the initial fields are not adequately described by the initial data (Hadeen, 1970). Therefore, modified Ekman equations are used to obtain the wind components diagnostically from temperature and height forecasts.

5.3.3 SIXLVL - Six-level Baroclinic Prediction Model. SIXLVL has been described by Palucci (1970). It is a quasi-geostrophic model patterned after the Cressman (1963) three-level model. SIXLVL is less sophisticated than the AWSPE and, as a result, the wind forecasts are, in general, of poorer quality.

SIXLVL is a synoptic-scale, whole-mesh model that forecasts heights, temperatures, and winds (stream functions) for the five layers between the six pressure levels 850, 700, 500, 300, 200, and 100 mb. SIXLVL is the primary forecast model in the Southern Hemisphere and is run on both the ontime and offtime cycles. The model is also used in the Northern Hemisphere, as will be discussed in more detail in a later paragraph. SIXLVL also serves as the backup to AWSPE.

SIXLVL is basically a vorticity forecast model. Vorticity forecasts are calculated from the quasi-geostrophic equation (Shuman, 1957) and then the stream function is computed diagnostically from the vorticity using constant values of the stream function at the boundaries. Vertical velocity (omega) is diagnosed at intermediate levels. Omega is set equal to zero at 100 mb and is determined by the terrain slope at the lower boundary.

SIXLVL was the primary forecast model at AFGWC from the late 1960s until AWSPE was implemented in 1975. TR6LVL, a version of SIXLVL, was run on the tropical grid but, according to verification statistics, did not beat persistence and was discontinued. Another version of SIXLVL, 3WINDO, is capable of forecasting for the half-mesh windows. In recent years, this version of SIXLVL has only been used to provide a facsimile chart for the European window.

5.3.4 1MPROG - 1000-mb Prognosis Model. 1MPROG is essentially a Reed (1963) model. It is the companion model to SIXLVL, as SIXLVL does not forecast below 850 mb. 1MPROG is the primary surface and 1000-mb forecast model for the Southern Hemisphere and is run on both the ontime and offtime cycles.

1MPROG forecasts the movement of the 1000-500 mb thickness pattern and then subtracts the thickness field from the 500-mb height forecast by SIXLVL. The principle problems encountered with the model are: (1) fictitious thickness is carried downstream in areas of high terrain and (2) diabatic processes are ignored, even though they can be important in areas such as continental-oceanic boundaries.

5.3.5 FIVLYR - Five-layer Cloud Forecast Model. FIVLYR provides half-mesh cloud forecasts for periods up to 48 h for five levels: gradient level, 850, 700, 500, and 300 mb. The model has been described by Collins (1970) and Jenkins (1978). FIVLYR forecasts temperature and condensation pressure spread (CPS). CPS is a moisture variable and is defined by the amount of vertical ascent (in mb) required to produce saturation.

The initial conditions for FIVLYR are derived from several sources. Each 3DNEPH eighth-mesh grid point is weighted to give a value at each FIVLYR half-mesh grid point. Then the upper 11 layers of cloud amount from the 3DNEPH are compacted into 5 layers. The resulting cloud amounts are converted empirically to CPS. If no clouds are present, CPS is derived from dewpoint depressions analyzed by MULTAN. Finally, initial temperatures are obtained from HUFANL, MULTAN, and SFC and are interpolated to half-mesh.

AWSPE winds in the NH and SIXLVL winds in the SH are used to compute three-dimensional trajectories for each grid point. At each point, the average vertical displacements in pressure along a trajectory are used to compute a new CPS value. The vertical displacements are sometimes modified for subgrid-scale processes. This new CPS value is then converted empirically to cloud amount. The model outputs include total and layered cloud amount, cloud type, temperature, dewpoint depression, Showalter stability index, icing, and a quantitative precipitation forecast (QPF).

5.3.6 HEMTMP - Hemispheric Temperature Model. HEMTMP produces a gradient-level temperature analysis and forecast. The model produces an eighth-mesh temperature analysis by reformatting the analysis fields from other models. Similarly, the temperature forecasts are reformatted to half mesh from available forecast fields. HEMTMP output is used by SFTMP. Although HEMTMP produces analyses and forecasts, it is used primarily as a forecast model.

5.3.7 HRCP - High-resolution Cloud Prognosis Model. HRCP is a cloud forecast model, similar to FIVLYR, that attempts to preserve the high spatial resolution obtainable from the initial 3DNEPH analysis. The CPS tendencies from FIVLYR are interpolated to fifteen levels and eighth-mesh and are then applied to the 3DNEPH initial fields. Due to hardware constraints, HRCP is run only when recent satellite data are received over an area of interest.

5.3.8 TRONEW - Tropical Cloud Model. TRONEW performs a 24-h diurnal persistence cloud forecast on the tropical grid. It uses the 3DNEPH cloud analysis and reanalyzes the cloud amounts into 3 layers (low, middle, and high) at half mesh. This cloud analysis is then used as a "diurnal persistence" forecast for 24 h later. TRONEW is run for both the Northern and Southern Hemisphere portions of the tropical grid.

6. THE AFGWC PRODUCTION CYCLE

The production cycle at AFGWC is the automated system of numerical analysis/forecast models and the interrelations of those models. The analysis/forecast models are linked in a way that permits them to produce all the basic meteorological analysis/forecast fields. These basic fields are both output directly and used as input to applications programs that produce mission-tailored products.

6.1 Specification of the production cycle

There are four major factors that influence the specific times at which a model is scheduled. These factors include: (1) a customer's operational requirements, (2) data receipt times, (3) the computer hardware, and (4) the computer software (that is, the numerical analysis/forecast model in use). Simply stated, timelines are critical. The value of an analysis or forecast decreases rapidly with time. Therefore, the objective is to produce the forecast fields as soon as possible. Forecasts cannot be made until analyses are done. Useful analyses cannot be made until enough data have been received. Finally, numerical analysis/forecast models cannot run any faster than the computer allows. All of these factors must be considered together in designing the actual production cycle.

6.1.1 Customer Requirements. Each customer (and not just AWS or AFGWC) specifies its operational requirements. The customer not only specifies the meteorological parameters and valid times but also the time that the product is required. For example, MAC tasked AFGWC to provide computer flight plan (CFP) support. This support requires AFGWC to produce a minimum of wind, temperature, and D-value forecasts for a number of atmospheric levels. MAC also requires that the CFP be transmitted by AFGWC within one hour of AFGWC's receipt of the CFP request. Of course, if the CFP arrives at the aircraft's departure point after the aircraft has departed, the CFP is of little value to MAC. Two points should be re-emphasized. First, each customer specifies its own requirements and not AFGWC. Second, a product's timeliness is just as important to the customer as its meteorological quality.

6.1.2 Data Receipt Times. Data begin arriving at data time and continue for several hours thereafter. AFGWC conducted surveys on surface and upper-air data receipt times for the 00Z, 06Z, 12Z, and 18Z cycles in 1977 and 1979, respectively. The results of these surveys are presented in Figures 1 and 2.

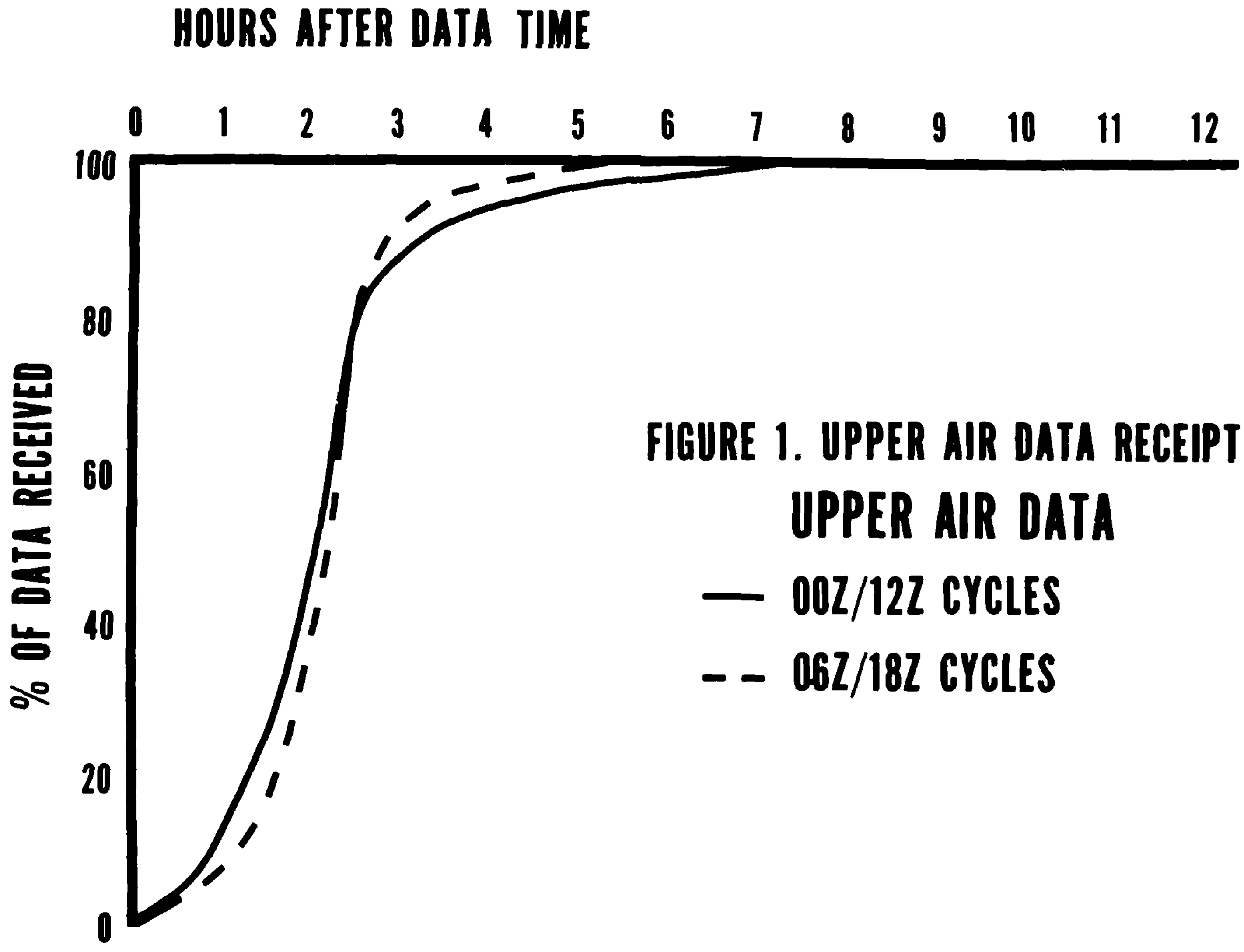


FIGURE 1. UPPER AIR DATA RECEIPT

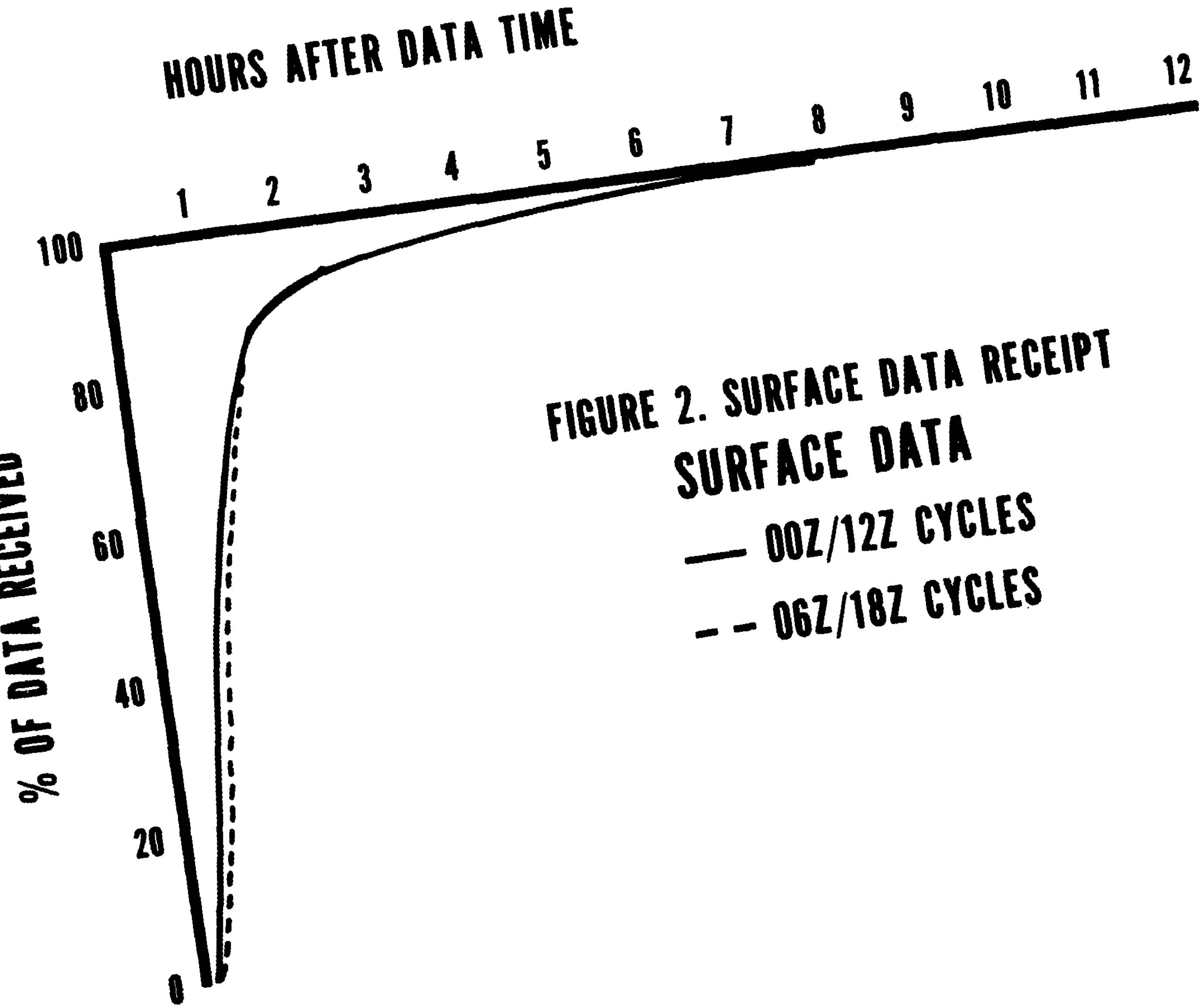


FIGURE 2. SURFACE DATA RECEIPT

For example, Figure 1 shows that about 68 percent of the total expected amount of surface data for the entire globe arrives by 1 hour after data time. Figure 2 shows that about 85 percent of the total expected global upper-air data arrives by 2 + 50 (2 hours, 50 minutes) after data time. Figure 1 and 2 show that the data arrive over a period of several hours. TR and SH data usually arrive later than NH data. The more data available to an analysis model, the more accurate the resulting analysis will be. However, the later the analysis model waits for more data, the later the analysis fields will be available to the forecast models. That is, the scheduled start time for an analysis model represents a compromise between waiting long enough to have sufficient data to produce an accurate analysis while at the same time running soon enough that the analysis fields are available to the forecast models at the required time.

6.1.3 Computer Hardware. AFGWC's Univac computers and associated peripheral devices are referred to as hardware. The rate at which the numerical forecast models can produce forecasts is limited by the capabilities of the computer hardware. The rate at which the numerical forecast models can produce forecasts is limited by the capabilities of the computer hardware. Factors that affect the capabilities of the computer hardware are, for example, the size of the computer memory and the number and speed of the central processing units.

6.1.4 Numerical Analysis/Forecast Models. The amount of computer time required by an analysis or forecast model depends on many factors. These factors include the model's overall complexity, the number of analysis/forecast parameters, the number of vertical levels used, and the horizontal grid increment. Generally, increasing the number of vertical levels, decreasing the horizontal grid increment, and incorporating more sophisticated physics into a forecast model are changes that will produce better forecasts. However, these same measures cause a forecast model to require more computer resources.

The customer requirements, data receipt times, and computer hardware have previously been determined. Therefore, the amount of computer time and memory size available for analysis/forecast models is predetermined. Models are chosen to produce the desired analysis/forecast fields within the available computer resources. The end result is that the operational analysis/forecast models are not always state-of-the-art models.

6.2 The AFGWC Production Cycle

Figure 3 is a complete flow chart containing the more than 80 runstreams that together constitute the 12-h production cycle. The reference time "T" in Figure 3 is either 00Z or 12Z. At first glance, Figure 3 appears to be extremely complicated. The lines represent the flow of analysis/forecast fields between models, with the arrows indicating the direction of flow. These lines and arrows therefore indicate which model must precede another model. For example, with the "Global Models" portion of Figure 3, there is an arrow from HUFGES to HUFANL. This arrow means that HUFANL requires fields generated by HUFGES. In other words, HUFGES is a predecessor for (must be run prior to) HUFANL.

Figure 3 also has lines at the bottom of the figure that exit at the end of the cycle. These lines represent output from one cycle used as input for the next cycle. In Figure 3, the corresponding inputs are at the top of the figure. For example, TWA7, the offtime tropical upper-air analysis, has a line extending to the bottom of Figure 3. Directly above that at the top of the figure is a corresponding input from TWA7. This TWA7 input in turn is used by HUFGES and TSHDEW.

Figure 3 is divided into two main portions. The cloud models are on the right and the conventional models are on the left. As mentioned earlier, cloud models are those models that analyze/forecast such variables as total and layered cloud amount, cloud type, icing, and snow depth and age. Conventional models are the remaining models; that is, they analyze/forecast the "conventional" meteorological variables, such as wind velocity, height, temperature, and surface pressure. Both main portions of Figure 3 are subdivided as follows:

Conventional Models	Cloud Models
1. Global	6. Global
2. Northern Hemisphere	7. Northern Hemisphere
3. Window	8. Southern Hemisphere
4. Tropical	
5. Southern Hemisphere	

Each subdivision will be discussed briefly.

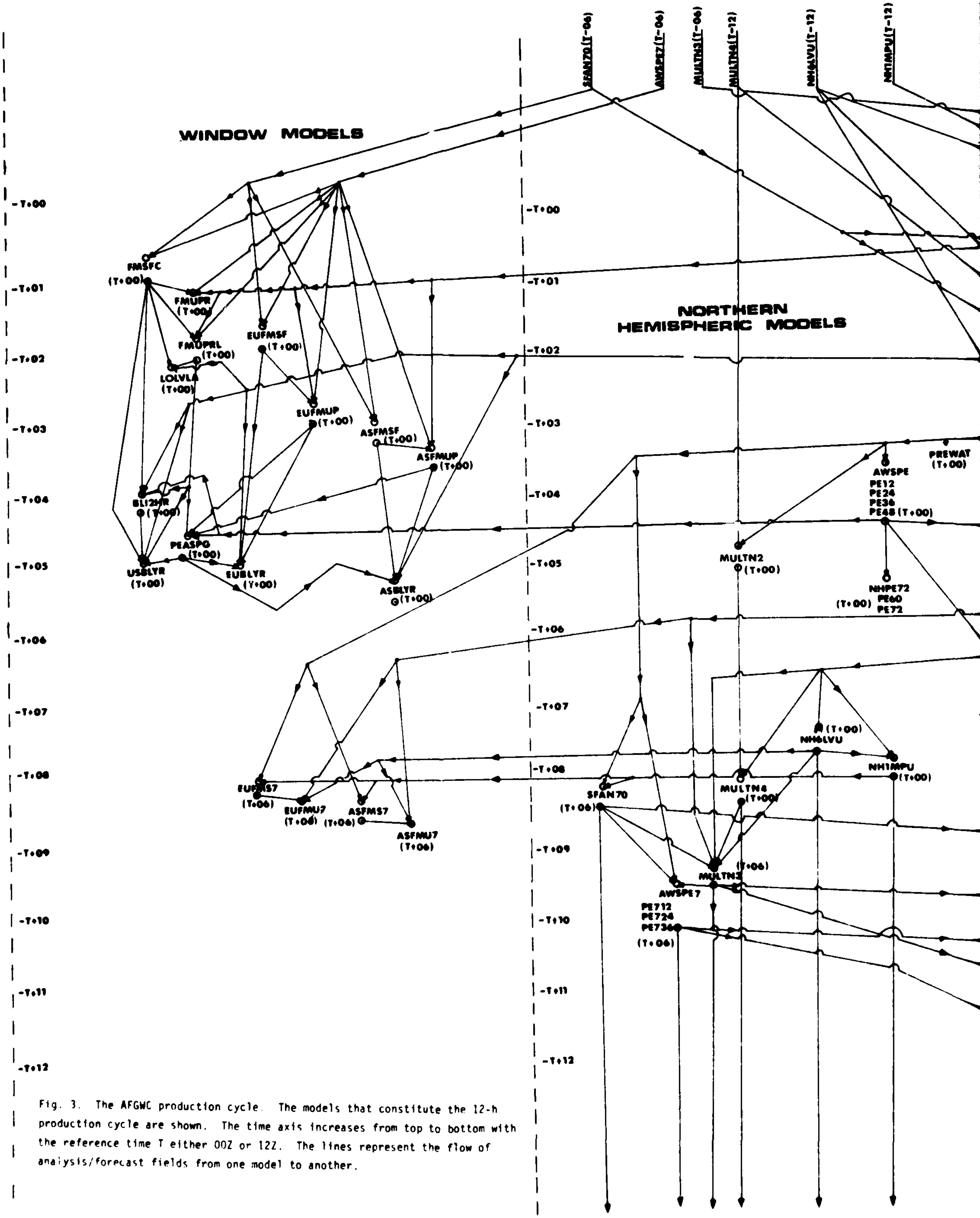
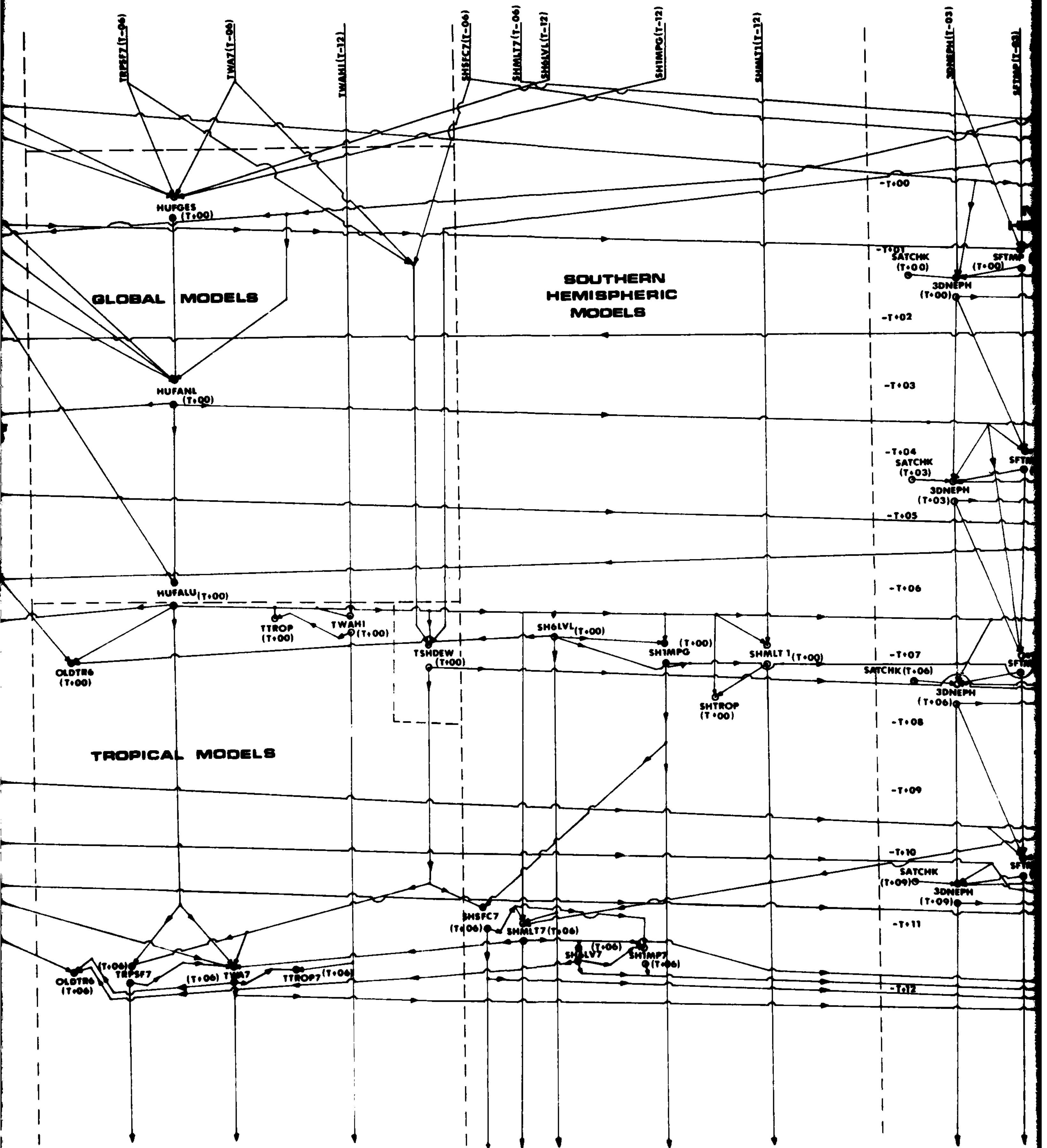
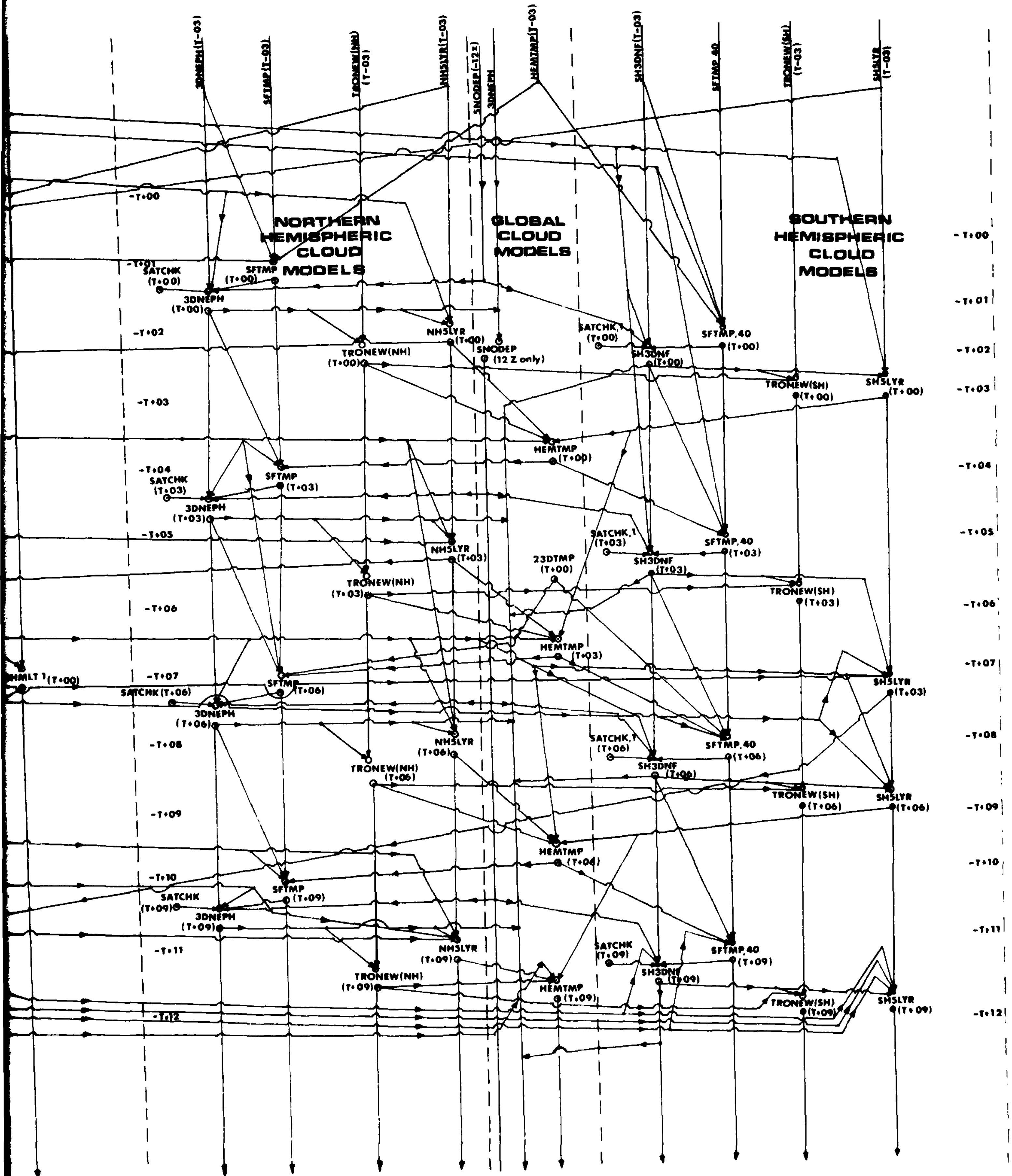


Fig. 3. The AFGWC production cycle. The models that constitute the 12-h production cycle are shown. The time axis increases from top to bottom with the reference time T either 00Z or 12Z. The lines represent the flow of analysis/forecast fields from one model to another.



TRPSF7(T-06)
TWA7(T-06)
TWAH1(T-12)
SHSFC7(T-06)
SHMLT7(T-06)
SH6LVL(T-12)
SH1MPG(T-12)
SHMLT1(T-12)
3DNEPH(T-03)
GLOBAL MODELS
SOUTHERN HEMISPHERIC MODELS
TROPICAL MODELS
HUFGES (T+00)
HUFANL (T+00)
HUFALU (T+00)
OLDTR6 (T+00)
TTROP (T+00)
TWAH1 (T+00)
TSHDEW (T+00)
SH6LVL (T+00)
SH1MPG (T+00)
SHMLT 1 (T+00)
SHTROP (T+00)
SATCHK (T+00)
3DNEPH (T+00)
SFTMP (T+00)
SATCHK (T+03)
3DNEPH (T+03)
SATCHK (T+06)
3DNEPH (T+06)
SATCHK (T+09)
3DNEPH (T+09)
SHSFC7 (T+06)
SHMLT7 (T+06)
SH6LV7 (T+06)
SH1MP7 (T+06)
OLDTR6 (T+06)
TRPSF7 (T+06)
TWA7 (T+06)
TTROP7 (T+06)
-T+00
-T+01
-T+02
-T+03
-T+04
-T+05
-T+06
-T+07
-T+08
-T+09
-T+10
-T+11
-T+12

2


NORTHERN HEMISPHERIC CLOUD MODELS
GLOBAL CLOUD MODELS
SOUTHERN HEMISPHERIC CLOUD MODELS
3DNEPH(T-03)
SFTMP(T-03)
TRONEW(NH) (T-03)
NH5LYR(T-03)
SNODEP(-12z)
3DNEPH
HEMTMP(T-03)
SH3DNF(T-03)
SFTMP,40
TRONEW(SH) (T-03)
SH5LYR (T-03)
-T+00
-T+01
-T+02
-T+03
-T+04
-T+05
-T+06
-T+07
-T+08
-T+09
-T+10
-T+11
-T+12
SATCHK (T+00)
SFTMP (T+00)
3DNEPH (T+00)
NH5LYR (T+00)
TRONEW(NH) (T+00)
SNODEP (12 Z only)
SATCHK,1 (T+00)
SH3DNF (T+00)
SFTMP,40 (T+00)
TRONEW(SH) (T+00)
SH5LYR (T+00)
HEMTMP (T+00)
SATCHK (T+03)
SFTMP (T+03)
3DNEPH (T+03)
NH5LYR (T+03)
SATCHK,1 (T+03)
SFTMP,40 (T+03)
SH3DNF (T+03)
23DTMP (T+00)
TRONEW(NH) (T+03)
TRONEW(SH) (T+03)
HEMTMP (T+03)
HMLT 1 (T+00)
SATCHK (T+06)
SFTMP (T+06)
3DNEPH (T+06)
SH5LYR (T+03)
NH5LYR (T+06)
SATCHK,1 (T+06)
SFTMP,40 (T+06)
SH3DNF (T+06)
TRONEW(NH) (T+06)
TRONEW(SH) (T+06)
SH5LYR (T+06)
HEMTMP (T+06)
SATCHK (T+09)
SFTMP (T+09)
3DNEPH (T+09)
NH5LYR (T+09)
SATCHK (T+09)
SFTMP,40 (T+09)
SH3DNF (T+09)
TRONEW(NH) (T+09)
HEMTMP (T+09)
TRONEW(SH) (T+09)
SH5LYR (T+09)

6.2.1 Conventional Global Models (reference Figure 4). The global conventional models are the three runstreams that constitute the Hough analysis system. This system provides a global spectral analysis for each ontime cycle. HUFGES derives global first-guess fields from the previous ontime NH and SH forecasts and the offtime TR analysis. The actual global analysis is done at two different times because of data receipt times. HUFANL runs at T+0305 and outputs a NH analysis. By this time 85 percent of all upper-air data has been received, including almost all of the expected NH data. A primary purpose of this NH analysis is to produce initial conditions for the forecast models. HUFALU runs at T+0606 and produces TR and SH analyses, as well as an updated NH analysis. By the HUFALU starting time, 98 percent of all expected upper-air data has been received. Note that HUFALU is the immediate predecessor for more runstreams than any other model.

6.2.2 Northern Hemisphere Conventional Models (reference Figure 5). The Northern Hemisphere models are the whole-mesh conventional models. In contrast, the window models are half-mesh Northern Hemisphere models and are considered in the next subdivision.

The ontime NH cycle begins after HUFANL with PREWAT's precipitable water analysis and AWSPE's 48-h forecast. NHPE72 extends the AWSPE forecast from 48 to 72 hours. AWSPE fields are then used by NH5LYR, the NH cloud forecast model. MULTN2 provides the ontime high-level (70-10 mb) analyses. No forecasts are made for these levels.

NH6LVU and NH1MPU produce 12-h upper-air and surface forecasts, which in turn are used as the first-guess fields for the analyses (HUFGES/HUFANL) that lead to the AWSPE forecasts for the next ontime cycle. This is done so that the AWSPE does not use its own 12-h forecast as the initial conditions for the next forecast. When the PE model was allowed to provide its own initial conditions at AFGWC, some forecast errors increased at an unacceptable rate. MULTN4 provides an ontime update of MULTN2 and includes all new ontime data received since MULTN2.

The offtime NH surface and upper-air analyses are performed by SFAN70 and MULTN3, respectively. These analyses are followed by the 36-h offtime forecast of AWSPE7. (By convention, the number 7 when used at or near the end of a runstream name usually indicates that the runstream is part of the offtime cycle.)

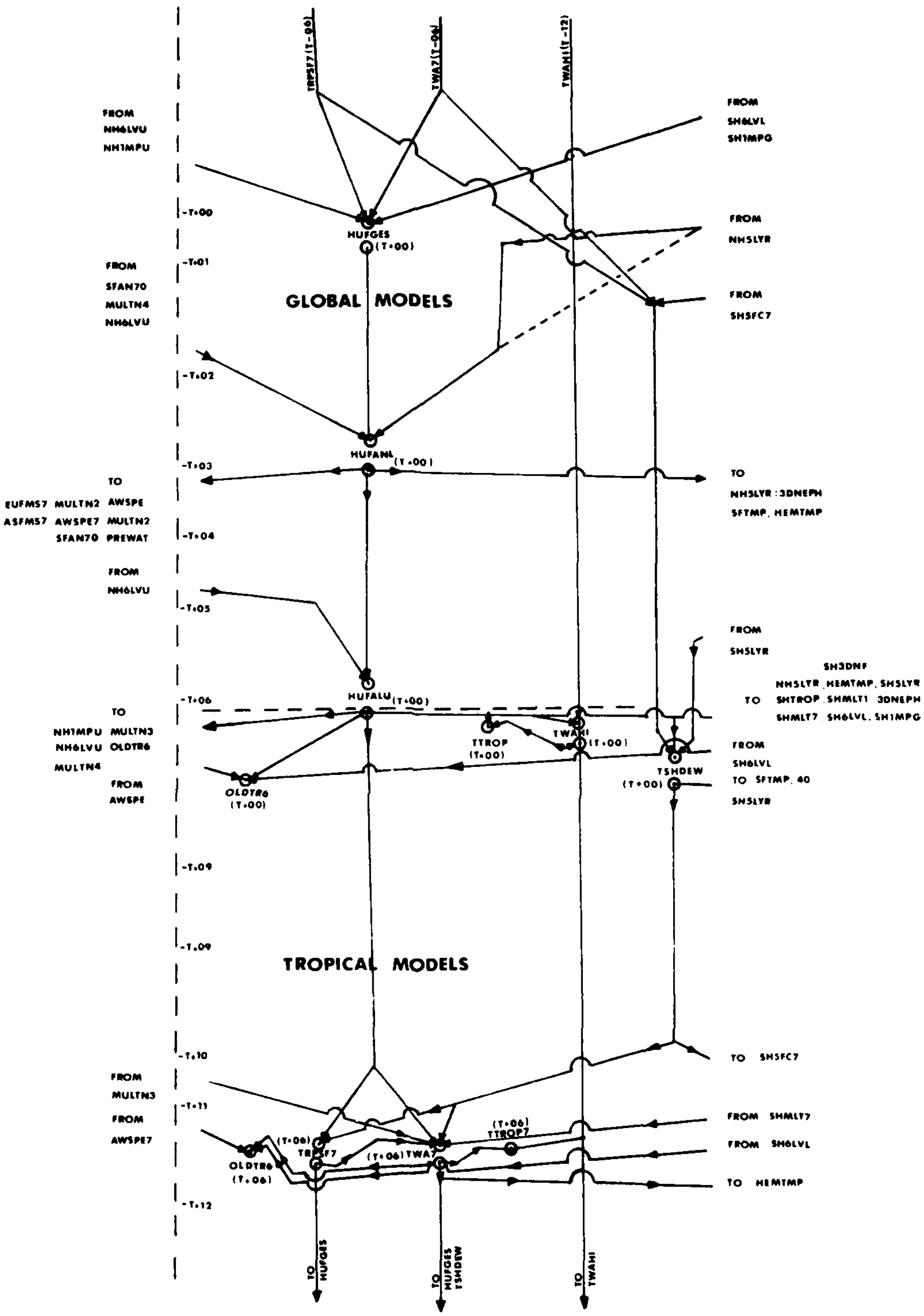


Fig. 4. Global conventional and tropical conventional models production cycle.

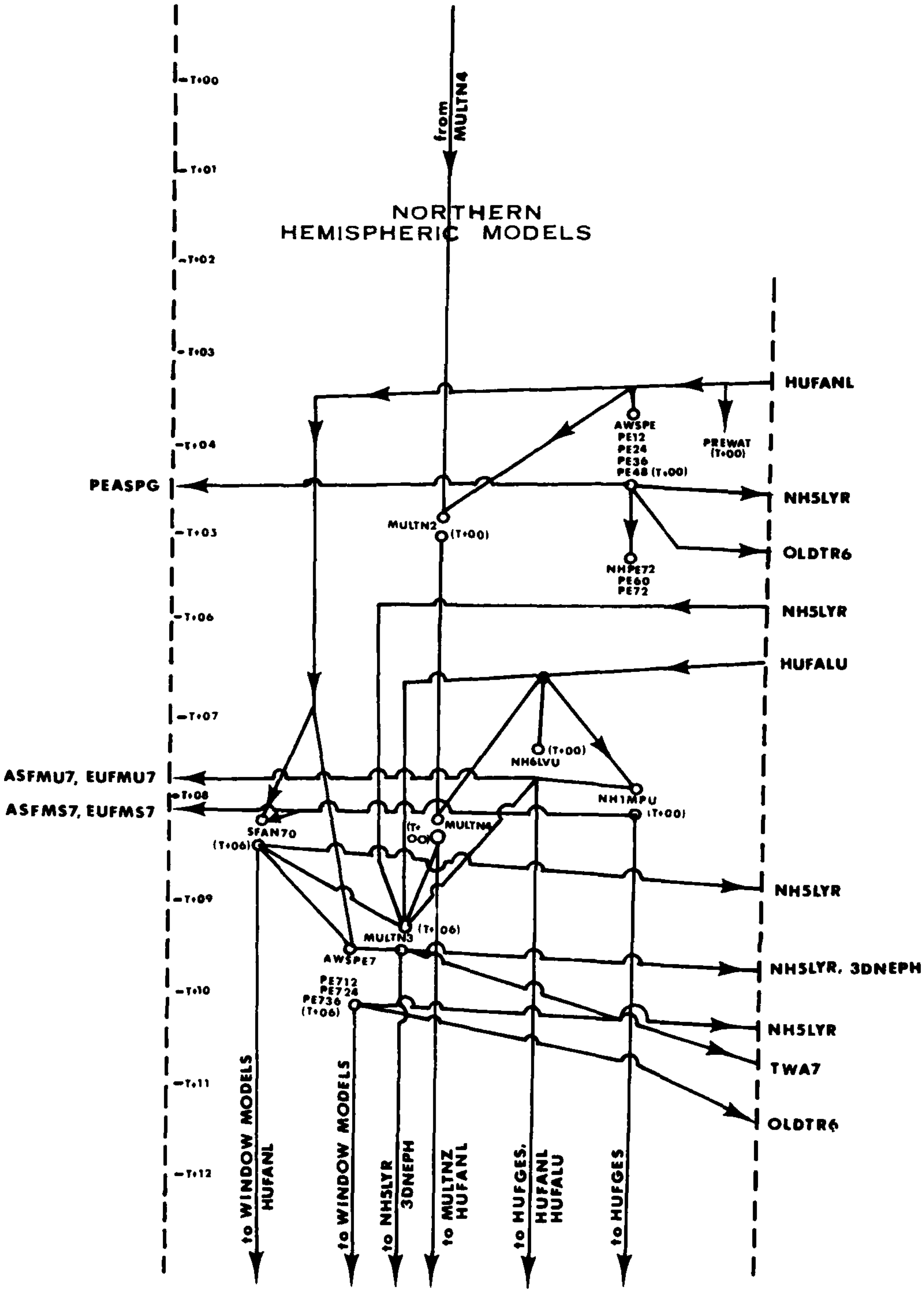


Fig. 5. Northern Hemispheric conventional models production cycle.

6.2.3 Window Conventional Models (reference Figure 6). The window models are half-mesh models run for the North American/U.S., European, and Asian windows. The ontime surface and upper-air analyses for the U.S., European, and Asian windows are FMSFC, FMUPR, EUFMSF, EUFMUP, ASFMSF, and ASFMUP, respectively. For the U.S. window, an update upper-air analysis, FMUPRL, is also run.

The BLM is a half-mesh model run over the windows. Before the BLM can be run, its boundary conditions must be specified. PEASPG interpolates AWSPE fields to the lateral and upper boundaries of the three windows. Then the window models, USBLYR, EUBLYR, and ASBLYR are executed.

LOLVLA is a low-level analysis for the U.S. window. BLI2HR is an "early-look" 12-h BLM forecast for the U.S. window. These products are used by forecasters of the AFGWC severe weather forecasting section to detect potential for severe weather.

6.2.4 Tropical Conventional Models (reference Figure 4). The ontime tropical analysis is done primarily by HUFALU. It is completed by TTROP (tropopause analysis), TSHDEW (tropical and SH dewpoint analysis),and OLDTR6 (stream function and vertical velocity analysis). Finally, the high-level (70-10 mb) tropical analyses are done by TWAHI.

The offtime tropical surface and upper-air analyses are performed by TRPSF7 and TWA7. The offtime tropical tropopause, stream function and vertical velocity analyses are accomplished by TTROP7 and OLDTR6.

6.2.5 Southern Hemisphere Conventional Models (reference Figure 7). The ontime SH analysis performed by HUFALU is run about 6 h into the 12 h cycle and therefore is not actually available until the beginning of the offtime cycle. The SH ontime analysis cycle is completed by SHTROP (tropopause analysis) and SHMLT1 (70-10 mb analyses). The ontime SH forecast models consist of surface and 1000 mb prognoses by SH1MPG and upper-air forecasts by SH6LVL. The offtime SH surface and upper-air analyses are produced by SHSFC7 and SHMLT7, respectively. Offtime SH 6-h surface and upper-air forecasts are produced by SH1MP7 and SH6LV7, respectively.

6.2.6 Global Cloud Models (reference Figure 8). The global cloud-related models are SNODEP, 23DTMP, and HEMTMP. SNODEP runs on the 12Z cycle only and produces a global analysis of snow depth and age. 23DTMP processes and stores the sea-surface temperatures received from FNOC. HEMTMP, which runs every 3

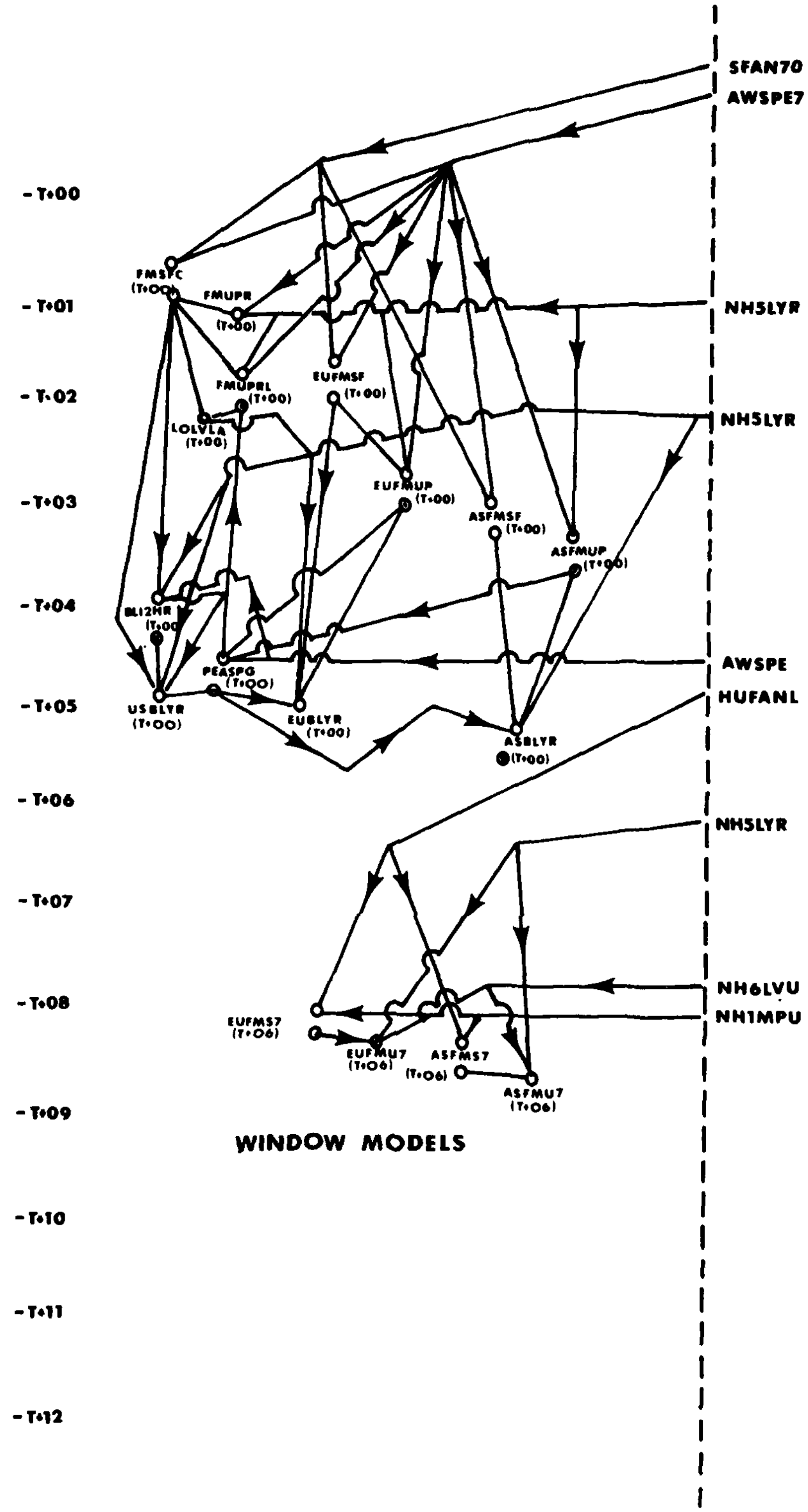


Fig. 6. Northern Hemisphere conventional models which are executed for the U.S., European, and Asian windows.

SOUTHERN HEMISPHERIC MODELS

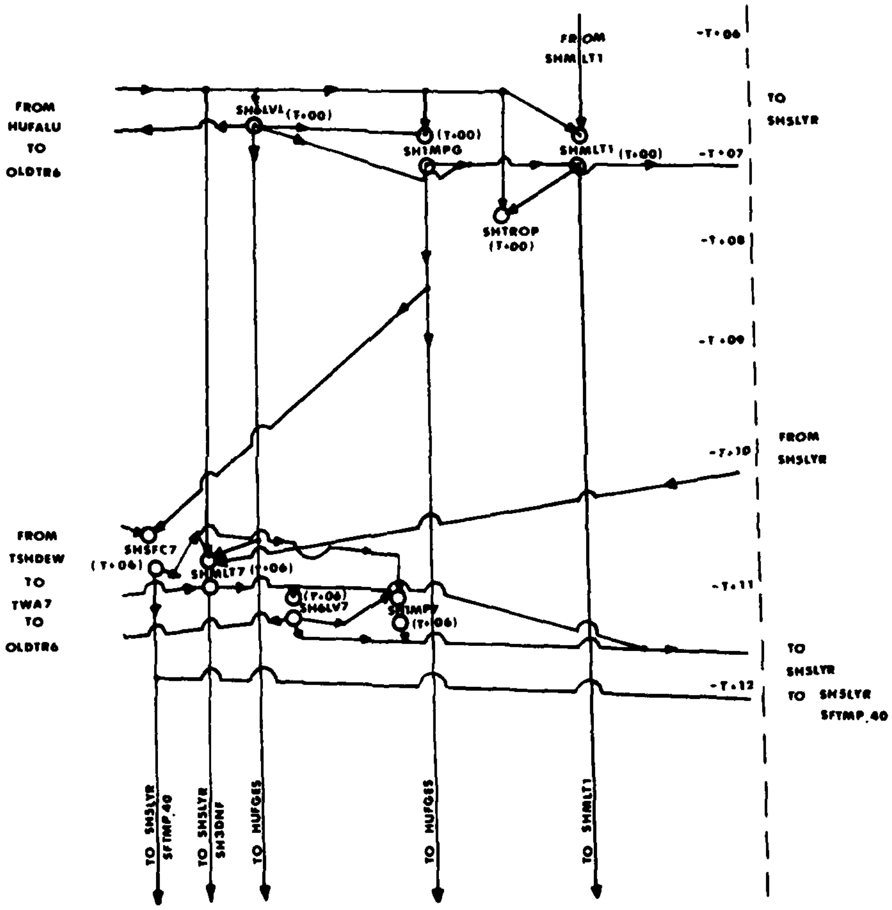


Fig. 7. Southern Hemispheric conventional models' production cycle.

hours, provides a global analysis and up to a 12-h forecast of temperature at the gradient level. The output from these three models is used both directly and indirectly by the NH or SH 3DNEPH models.

6.2.7 Northern Hemisphere Cloud Models (reference Figure 8). The Northern Hemisphere cloud models are run on a 3-h cycle. SFTMP performs a NH eighth-mesh surface temperature analysis, which is used by 3DNEPH in the determination of clouds from IR satellite data. SATCHK is the satellite data preprocessor for 3DNEPH. 3DNEPH updates the entire Northern Hemisphere 3-D nephanalysis. TRONEW provides a diurnal persistence cloud forecast for the Northern Hemisphere portion of the tropical grid. NH5LYR combines forecast winds from the latest available AWSPE/AWSPE7 forecasts and the latest cloud analysis from 3DNEPH and produces a 48-h Northern Hemisphere cloud forecast. The production cycle is designed so that NH5LYR runs immediately after 3DNEPH is completed, if AWSPE/AWSPE7 are also finished.

6.2.8 Southern Hemisphere cloud models (reference Figure 9). The production cycle for the SH cloud models is analogous to the cycle for the NH cloud models. SATCHK,1 and SFTMP,40 are the SH equivalents to SATCHK and SFTMP. (A number following a runstream name is the specific option to be executed). Note that the Southern Hemisphere cloud models are scheduled later than their Northern Hemisphere counterparts. This later scheduling arises because the SH data, in general, are available later than the NH data and because fewer operational requirements exist in the SH. TRONEW provides a diurnal persistence cloud forecast for the SH portion of the tropical grid. SH3DNF is the Southern Hemisphere counterpart to 3DNEPH. Immediately after SH3DNF, SH5LYR provides a 24-h Southern Hemisphere cloud forecast.

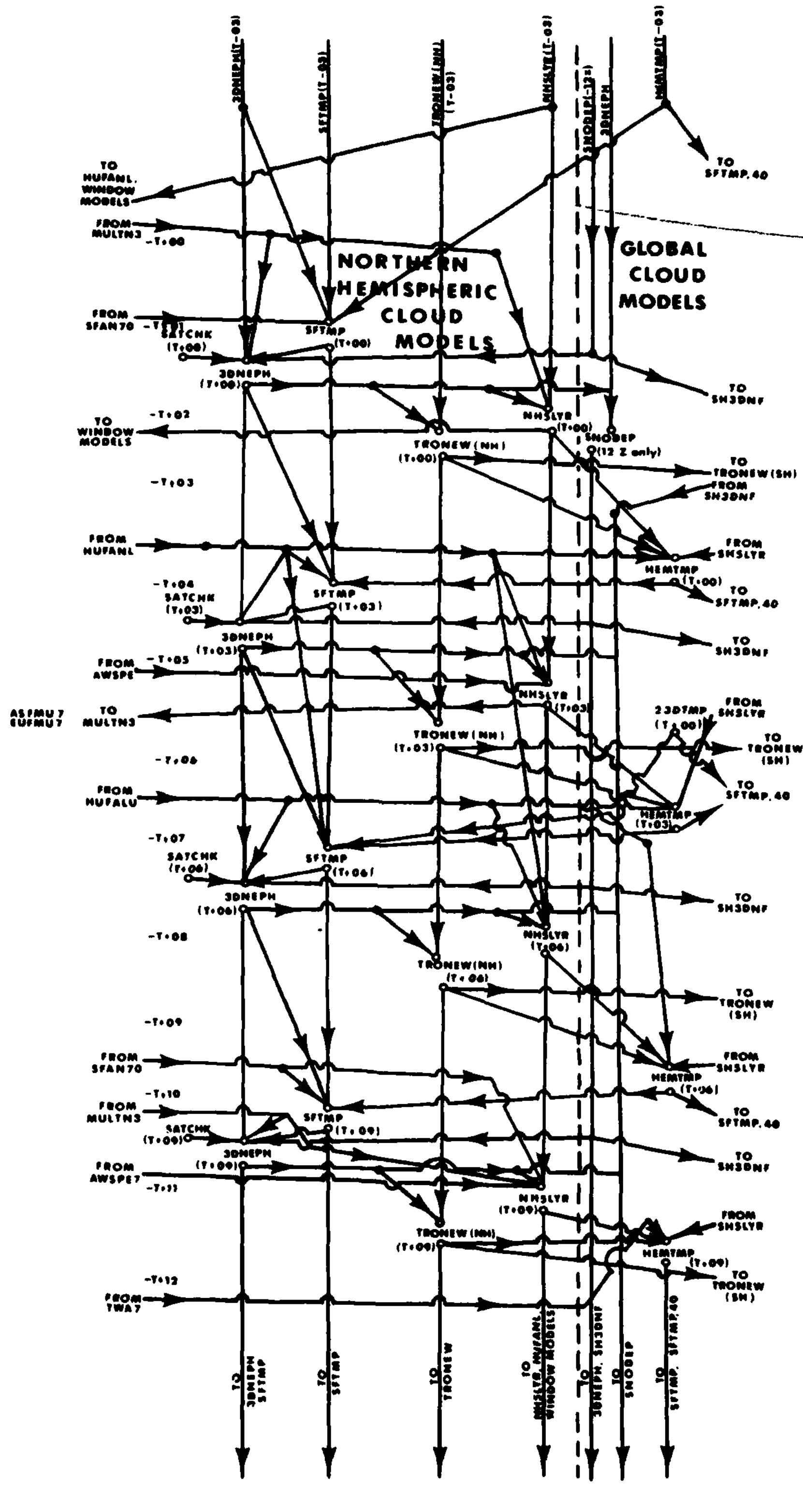


Fig. 8. Global cloud and Northern Hemispheric cloud models' production cycle.

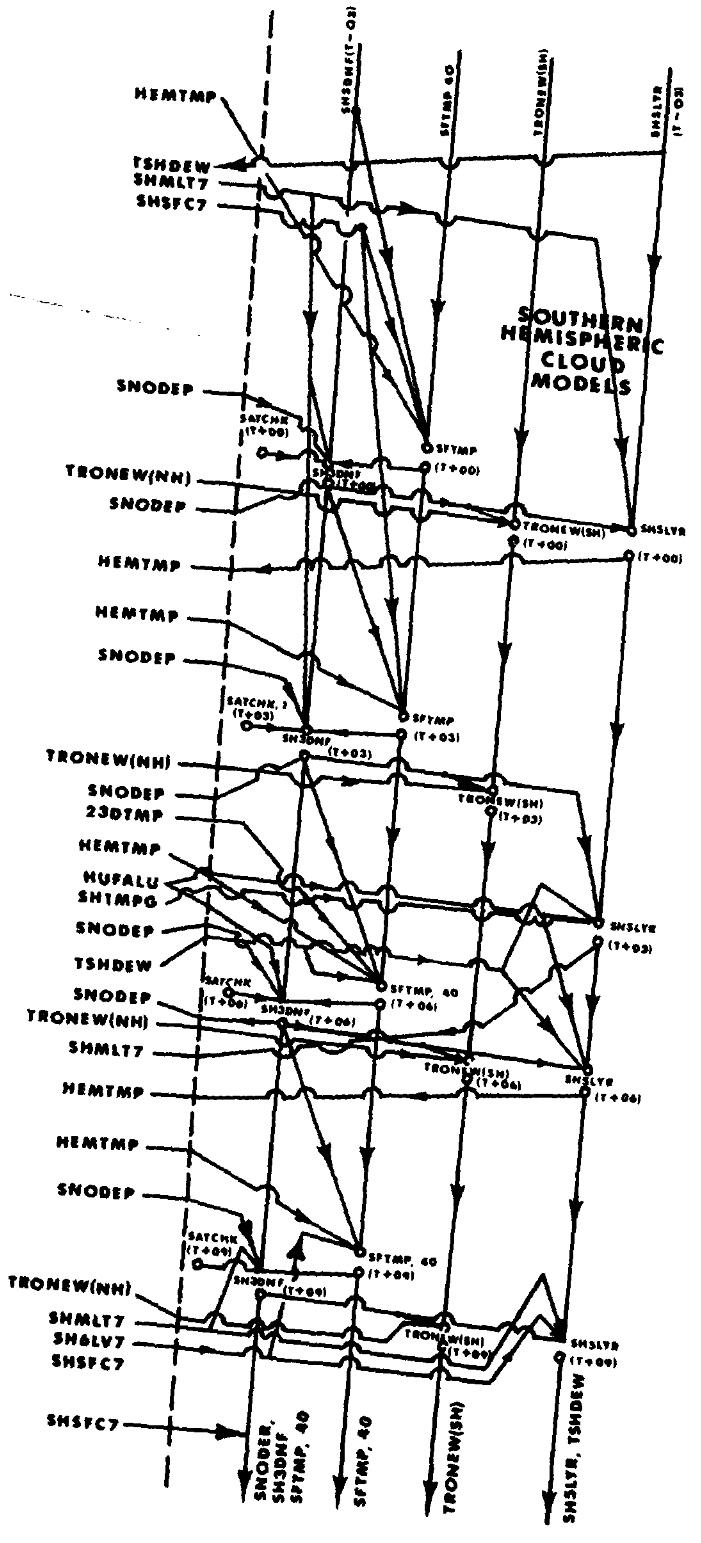


Fig. 9. Southern Hemispheric cloud models' production cycle.

7. SUMMARY

AFGWC produces meteorological analyses, forecasts, and tailored products for AWS/AFGWC's myriad customers. The meteorological data base of analysis/forecast fields is built by the AFGWC production cycle. The production cycle consists of numerous analysis/forecast models and their interconnections.

A wide variety of analysis and forecast models with varying degrees of sophistication are used at AFGWC. These models, as well as the production cycle, have evolved over the past two decades. This Technical Note discusses the cloud and conventional (non-cloud) models. These models analyze/forecast on grids of eighth, half, and whole mesh (the tropical grid is considered whole mesh).

7.1 The Present System

The principle AFGWC analysis models are HUFANL and 3DNEPH. HUFANL performs a global spectral analysis based on Hough functions. Analyzed are winds and heights for the mandatory pressure levels from 1000 mb to 100 mb. Surface pressure and surface winds are then extrapolated. Temperatures are derived hydrostatically from the height fields. HUFANL produces a more meteorologically appearing analysis in data-sparse areas than any other AFGWC conventional analysis model.

3DNEPH analyzes cloud and cloud-related parameters on an eighth-mesh grid. It is the only known operational nephanalysis model that merges conventional and satellite data. 3DNEPH provides, among other parameters, total and layered cloud amounts for 15 levels from the surface to 55,000 ft.

The principle AFGWC forecast models are AWSPE and FIVLYR. AWSPE is a dry version of the Shuman and Hovermale (1968) PE model, which was implemented at NMC in 1966. AWSPE is a six-layer whole-mesh model that forecasts wind, height (D-value), and temperature from the surface to 100 mb. Surface and tropopause pressures are also forecast. Due to hardware constraints, AWSPE is run only for the Northern Hemisphere. FIVLYR forecasts clouds for five layers on a half-mesh grid. The model reformats the 15-layer eighth-mesh 3DNEPH analysis to a five-layer half-mesh analysis. Whole-mesh temperature analyses are interpolated to half mesh. From horizontal and vertical winds forecast by AWSPE, FIVLYR then computes trajectories, which are used to derive the forecasts of clouds and temperatures.

The AFGWC analysis and forecast models are linked together to form the AFGWC production cycle. The production cycle is determined by customer requirements, data receipt times, computer hardware, and the analysis/forecast models themselves. Timeliness is important to most customers. That is, a product's timeliness is just as important as the product's meteorological quality. These considerations taken together lead to at least the following:

a. To meet production timelines, the analysis/forecast models are not always state-of-the-art models.

b. The production cycle is indeed complex.

We have divided the production cycle into cloud and conventional models and further subdivided these into geographical sections. The divisions were made to aid in understanding the overall cycle. The cloud models cycle within a three-hour period. The conventional models cycle within a twelve-hour period. Each twelve-hour cycle is composed of two six-hour cycles, referred to as ontime and offtime cycles. More emphasis is placed on the ontime cycle because more data are available for that cycle. For both cloud and conventional models, more emphasis is placed on the Northern Hemisphere because more data are available and more operational requirements exist there.

The production cycle depicted in Figure 3 will change in the coming months and years. Nevertheless, this effort to document the production cycle has already yielded dividends on the use and management of the automated analysis/forecast system. We will strive to maintain a current version of Figure 3, which will continue to yield dividends in the future.

7.2 The Future System

The development of new or modified cloud and conventional models depends on future operational requirements. New development also depends on computer hardware. AFGWC cannot run much more meteorologically sophisticated models on the current AFGWC computer systems. In fact, some of the development discussed in subsequent paragraphs would require the availability of more powerful computers. Hence we emphasize that the majority of these plans is conceptual only.

AWS recently tasked the Technical Development Branch of AFGWC with the development of a new 3DNEPH model. The new 3DNEPH model is referred to as the Real-time NEPH model because it will eliminate the duplicate processing of satellite data and concentrate on the processing of satellite and conventional data as they are received at AFGWC. The new model will also have the ability to "trace" the analysis at a particular point and level. That is, the analysis can be broken down into the various input data that produced the analysis. The current 3DNEPH does not have this capability. The Real-time NEPH is scheduled for implementation in 1982.

The USAF Scientific Advisory Board (SAB) on Cloud Forecasting recently issued a report that briefly described models that would potentially lead to improved cloud forecasts at AFGWC. These models are presently only in the conceptual stage. The SAB recommended the use of a global model on a grid finer than a whole-mesh grid to forecast winds, temperatures, heights, moisture, and clouds. The global model may be a spectral model. For high-resolution forecasts over limited areas, a high-resolution (horizontal and vertical), relocatable grid-point window model would be used. The global and window models would require high-resolution cloud and conventional analysis models. The implementation of all these models would permit improved analyses and forecasts and would also replace many of the existing cloud and conventional models. The SAB also recommended an order of magnitude increase in the computer resources dedicated to building the meteorological data base. This increase would be required if AFGWC is to run these high-resolution global and window forecast models.

8. APPENDIX A - GLOSSARY

This glossary is an alphabetical listing of the abbreviations, definitions, model acronyms, runstream names, etc., used in this Technical Note.

AFGWC - Air Force Global Weather Central.

AGL - Above ground level.

AIREP - Aircraft report.

ASBLYR - Version of BLM for the Asian window; provides 0-36 h boundary-layer forecasts of height, wind, temperature, and moisture for the 00Z and 12Z cycles.

ASFMSF - Half-mesh surface/1000 mb analysis model for the Asian window run for the 00Z and 12Z cycles; provides half-mesh analyses of 1000 mb height, wind, temperature, and moisture, as well as surface pressure and temperature.

ASFMS7 - Version of ASFMSF run for the 06Z and 18Z cycles.

ASFMUP - Half-mesh upper-air analysis model for the Asian window run for the 00Z and 12Z cycles; provides half-mesh analyses of height, wind, temperature, and moisture for the mandatory pressure levels from 850 mb to 100 mb.

ASFMU7 - Version of ASFMUP run for the 06Z and 18Z cycles.

Asian window - The half-mesh window covering eastern Asia.

AWN - Automated Weather Network.

AWS - Air Weather Service.

AWSPE - Air Weather Service Primitive-equation model; primary whole-mesh forecast model for the NH octagon run for the 00Z and 12Z cycles; provides 0-48 h forecasts for mandatory pressure levels from the earth's surface to 100 mb.

AWSPE7 - Version of AWSPE run for the 06Z and 18Z cycles; provides 0-36 h forecasts.

BLM - Boundary Layer (forecast) Model; provides 0-36 h forecasts of height, wind, temperature, and moisture for the half-mesh windows.

BL12HR - Version of half-mesh boundary-layer forecast model; provides 0-12 h forecasts of height, wind, temperature, and moisture for eight levels from the earth's surface to 1600 m for the U.S. window. BL12HR is run for the 00Z and 12Z cycles.

Cloud Model - A model concerned primarily with the analysis/forecast of clouds and cloud parameters.

COMSAT - Communications Satellite Corporation.

Conventional Model - A non-cloud model. That is, a model that analyses/forecasts conventional variables such as heights, winds, and temperatures.

CPS - Condensation pressure spread. The pressure change required for a parcel to attain saturation.

Cycle - A 3-, 6-, or 12-h period during which a set of models is executed. That same set of models is repeated on the next cycle (reference Section 1.1).

D - D-value; deviation of height from the reference value for a particular level.

DMSP - Defense Meteorological Satellite Program.

DOD - Department of Defense

EUBLYR - Version of half-mesh boundary layer forecast model for the European window; provides 0-36 h boundary layer forecasts of height, wind, temperature, and moisture for the 00Z and 12Z cycles.

EUFMSF - Half-mesh surface/1000-mb analysis model for European window run for the 00Z and 12Z cycles; provides half-mesh analyses of 1000-mb height, wind, temperature, and moisture as well as surface pressure and temperature.

EUFMS7 - Version of EUFMSF run for the 06Z and 18Z cycles.

EUFMUP - Half-mesh upper-air analysis model for European window run for the 00Z and 12Z cycles; provides half-mesh analyses of height, wind, temperature, and moisture for mandatory pressure levels from 850 mb to 100 mb.

EUFMU7 - Version of EUFMUP run for 06Z and 18Z cycles.

European window - The half-mesh grid covering Europe and western Asia.

FIVLYR - Five Layer Cloud Forecast Model; provides half-mesh cloud forecasts for five layers for periods of 0-48 h.

FMSFC - Fine-mesh Surface Analysis Model; half-mesh surface/1000-mb analysis model for U.S. window run for the 00Z and 12Z cycles; provides half-mesh analyses of 1000-mb height, wind, temperature, and moisture, as well as surface pressure and temperature.

FMUPR - Half-mesh Upper-air Analysis Model for U.S. window run for 00Z and 12Z cycles; provides half-mesh analyses of height, wind, temperature, and moisture for mandatory pressure levels from 850 mb to 100 mb.

FMUPRL - Update version of FMUPR run for the 00Z and 12Z cycles.

FNOC - Fleet Numerical Oceanographic Center, Monterrey, CA

GMRFBU - Version of AWSPE that provides 72-96 h forecasts for the NH; requested by the Medium-range Forecast Section when NMC medium-range products are unavailable.

GOES - Geostationary Operational Environmental Satellite.

Gradient level - The level whose pressure is 50 mb less than the surface pressure.

Grid - The set of uniformly spaced points at which values for meteorological parameters are defined by numerical analysis/forecast models.

Grid increment - The distance between adjacent points on a grid.

HEMTMP - Eighth-mesh Temperature Forecast Model run every 3h; provides gradient-level temperature forecasts used by SFTMP and SFTMP,40.

HIANAL - High-level Analysis Model; provides an analysis of the mandatory levels from 70 through 10 mb.

HUFALU - Update version of HUFANL run for 00Z and 12Z cycles; provides analyses for NH and SH octagons and the TR grid.

HUFANL - Hough Global Whole-mesh Analysis Model run for 00Z and 12Z cycles; provides analyses of height, wind, temperature for mandatory pressure levels from the earth's surface to 100 mb. Included for the NH octagon are analyses of moisture and the tropopause.

HUFGES - Model that prepares the first guess for HUFANL.

IR - Infrared

LOLVLA - Version of BLM forecast model that provides a low-level analysis used by the Severe Weather Forecast Section of AFGWC; run for the 00Z and 12Z cycles.

MLTN1A - Update version of MULTN1 for the 00Z and 12Z cycles for the NH octagon.

MSL - Mean sea level.

MULTAN - Multi-level Analysis Model; provides upper-air analyses for the 00Z, 06Z, 12Z, and 18Z cycles for the SH octagon. It is the backup analysis model for the NH octagon. Temperature, height, winds, and dewpoint depression are analyzed at mandatory levels from 850 through 100 mb.

MULTN1 - Backup 00Z and 12Z upper-air analysis for the NH octagon.

MULTN2 - Whole-mesh High-level Analysis Model for the NH octagon; run for the 00Z and 12Z cycles; provides analyses of height, wind, and temperature for the mandatory pressure levels from 70 mb to 10 mb.

MULTN3 - Whole-mesh analysis model for the NH octagon; provides analyses of height, wind, temperature, and moisture for the mandatory pressure levels from 850 mb to 100 mb; run for the 06Z and 18Z cycles.

MULTN4 - Update version of MULTN2; run for the 00Z and 12Z cycles.

NEPH CYCLE - A 3-h cycle during which the NH and SH cloud models are executed.

NH - Northern Hemisphere

NHPE72 - Version of AWSPE that provides 48-72 h forecasts; run for the 00Z and 12Z cycles.

NH5LYR - Half-mesh cloud forecast model for the NH octagon; provides 0-48 h cloud forecasts for the 03Z, 09Z, 15Z, and 21Z cycles; provides 0-24 h forecasts for the 00Z, 06Z, 12Z, and 18Z cycles.

NH1MPG - Version of 1MPROG that provides the backup surface forecast for the 00Z and 12Z cycles on the NH octagon.

NH1MPU - Whole-mesh 1000 mb/surface forecast model used to update the 0-12 h AWSPE forecasts for the NH octagon; run for the 00Z and 12Z cycles.

NH1MP7 - Version of NH1MPG for the 06Z and 18Z cycles.

NH1M7U - Update version of NH1MP7.

NH6LVL - Version of SIXLVL for the NH octagon; provides backup 0-48 h forecasts for AWSPE.

NH6LVU - Whole-mesh forecast model used to update the 0-12 h AWSPE forecasts (850-100 mb) for the NH octagon; run for the 00Z and 12Z cycles.

NH6L72 - Version of SIXLVL that follows NH6LVL and provides 48-72 h forecasts.

NMC - National Meteorological Center, Camp Springs, Maryland.

NOAA - National Oceanic and Atmospheric Administration.

NWP - Numerical weather prediction.

Octagon - The whole-mesh grid used for the NH and SH.

Offtime - Refers to the 6-h cycle beginning at 06Z or 18Z.

OLDTR6 - Whole-mesh analysis model for the Tropics; adapted from the SIXLVL forecast model; provides analyses of vertical motion and stream function; run for the 00Z, 06Z, 12Z, and 18Z cycles.

Ontime - Refers to the 6-h cycle beginning at 00Z or 12Z.

PE - Primitive equation.

PEASPG - Half-mesh interpolation model; interpolates whole-mesh AWSPE forecasts to half-mesh window grids over the U.S., Europe, and Asia for use by USBLYR, EUBLYR, and ASBLYR; run for the 00Z and 12Z cycles.

PE12 - Ontime version of AWSPE that interpolates the 12-h forecast field from sigma to pressure surfaces and stores them in the data base. Note that versions exist for every 12 h interval through PE72. PE712, PE724, and PE736 are the offtime versions.

PREWAT - Precipitable water analysis model; provides an analysis for the 00Z and 12Z cycles for the NH octagon.

Production Cycle - The complete set of cloud and conventional models that are executed during the 12-h period beginning at 00Z or 12Z.

q - Specific humidity.

QPF - Quantitative precipitation forecast.

RAOB - Radiosonde or rawinsonde report.

Runstream - A set of Univac computer control statements that executes a model.

RTWX - Real-time weather program; a computer program that receives conventional data from outside sources and stores the data in the AFGWC meteorological data base.

SATCHK - Satellite data preprocessor for 3DNEPH.

SATCHK,1 - Satellite data preprocessor for SH3DNF.

SFANAL - Version of SFC that provides a backup surface analysis for the 00Z and 12Z cycles for the NH octagon.

SFAN70 - Whole-mesh surface/1000 mb analysis model for the NH.

SFTMP - Uses input from HEMTMP and temperature observations to produce the temperature analysis required by the 3DNEPH.

SFC - Surface analysis model; provides a surface analysis of pressure, temperature, and dewpoint depression and analysis of 1000 mb winds and D-values. Versions of the model are run for the 00Z, 06Z, 12Z, and 18Z cycles for the NH and SH octagons and the TR grid.

SFTMP,40 - Version of SFTMP run to provide input for SH3DNF.

SH - Southern Hemisphere.

SHMLTN - Version of MULTAN for the 00Z and 12Z cycles and the SH octagon.

SHMLTU - Update version of SHMLTN.

SHMLTO - Version of HIANAL for the 00Z and 12Z cycles for the SH octagon.

SHMLT1 - Version of MULTN2 for the SH octagon; run for 00Z and 12Z cycles.

SHMLT7 - Version of MULTN3 for the SH octagon; run for 06Z and 18Z cycles.

SHSFC - Version of SFC for SH octagon; run for 00Z and 12Z cycles.

SH1MPG - Whole-mesh surface/1000 mb forecast model for the SH octagon run for 00Z and 12Z cycles; provides 0-48 h forecasts for the surface and 1000 mb.

SH1MP7 - Version of SH1MPG used for 06Z and 18Z cycles; provides 0-6 h forecasts.

SH3DNF - Version of 3DNEPH used for the SH.

SH5LYR - Version of NH5LYR used for the SH; provides 0-24 h cloud forecasts.

SH6LVL - Whole-mesh forecast model for the SH octagon used for the 00Z and 12Z cycles; provides 0-48 h forecasts of height, wind, and temperature for mandatory pressure levels from 850 mb to 100 mb.

SH6LV7 - Version of SH6LVL used for 06Z and 18Z cycles; provides 0-6 h forecasts.

SIXLVL - Six-level baroclinic forecast model; provides the primary upper-air forecasts for the 00Z, 06Z, 12Z, and 18Z cycles for the SH octagon. It is the backup forecast model to AWSPE and provides an updated forecast for the NH octagon.

SLP - Sea level pressure.

SNODEP - Snow depth analysis model; provides a global analysis of snow depth once daily.

T - Temperature. Also, production cycle start time (00Z or 12Z).

T_d - Dewpoint temperature.

$T-T_d$ - Dewpoint depression.

TN - Technical Note.

TR - Tropics or tropical.

TROP - Tropopause analysis model; provides analysis of tropopause pressure, temperature, and height. There are versions for the NH and SH octagons and for the TR grid.

TROPSF - Tropical surface analysis model; version of SFC designed for the TR grid.

TROPUA - Tropical upper-air analysis model; essentially a version of MULTAN for the TR grid.

TRONEW - Tropical cloud forecast model; provides 0-24 h half-mesh forecasts.

TRPSF7 - Version of SFAN70 for the TR grid; run for the 06Z and 18Z cycles.

TSHDEW - Version of MULTN3 that provides the moisture analyses for the SH octagon and the TR grid; run for the 00Z and 12Z cycles.

TTROP - Whole-mesh tropical tropopause analysis model for the 00Z and 12Z cycles.

TTROP7 - Version of TTROP for the 06Z and 18Z cycles.

TWAHI - Version of MULTN2 for the TR grid; run for the 00Z and 12Z cycles.

TWAONT - Version of TROPUA that provides an upper-air analysis for the 00Z and 12Z cycles for the TR grid.

TWA2 - Version of TWAHI that uses climatology for the first-guess field instead of the previous analysis.

TWA7 - Version of TROPUA that provides a tropical upper-air analysis for the 06Z and 18Z cycles.

u - East-west component of wind velocity.

U.S. Window - The half-mesh grid covering most of the North American continent.

USBLYR - Version of half-mesh boundary-layer forecast model for U.S. windows; provides 0-36 h forecasts.

v - North-south component of wind velocity.

1HRCP - Version of HRCP that provides a cloud forecast for a limited number of 3DNEPH boxes; run for DMSP satellite F3.

1SPTNF - Version of 3DNEPH that processes the quarter orbit one of DMSP satellite data. Quarter orbit one is the NH ascending quarter orbit.

2SPTNF - Same as 1SPRINT except for quarter orbit 2.

23DTMP - Eighth-mesh program that provides a sea surface temperature analysis for use by 3DNEPH and SH3DNF.

3DNEPH - Three-dimensional Nephanalysis Model; eighth-mesh cloud analysis model for the NH.

3DNEPH Box - The eighth-mesh grid used by the 3DNEPH model. The 3DNEPH box is a square with 64 eighth-mesh (8 whole-mesh) grid points on a side.

3SPTNF - Same as 1SPRINT except for SH data, quarter orbit 3.

4SPTNF - Same as 1SPRINT except for SH data, quarter orbit 4.

Δx - Grid increment; also called grid spacing, grid mesh, and grid interval.

9. REFERENCES

Barnes, S.L., 1964: Technique for maximizing details in numerical weather map analysis. J. Appl. Meteor., 3, 396-409.

Brown, J.F., 1973: Tropical analysis model. AFGWC Tech Memo 73-3, AFGWC, Air Weather Service (MAC), Offutt AFB, NE, 15 pp.

Collins, R.W., 1970: AFGWC multilevel cloud model. AFGWC Tech Memo 70-10, AFGWC, Air Weather Service (MAC), Offutt AFB, NE, 35 pp.

Cressman, G.P., 1959: An operational objective analysis system. Mon. Wea. Rev., 87, 367-374.

Cressman, G.P., 1963: A three-level model suitable for daily numerical forecasting. NMC Tech Memo 22, 20 pp.

Flattery, T.W., 1971: Spectral models for global analysis and forecasting. Proc. Sixth AWS Technical Exchange Conference, U.S. Naval Academy, 21-24 Sep 1970. Air Weather Service Tech Report 242, 42-54.

Fleming, R.J., 1969: AFGWC fine-mesh upper-air analysis model. AFGWC Tech Memo 69-2, AFGWC, Air Weather Service (MAC), Offutt AFB, NE, 15 pp.

Fye, F.K., 1978: The AFGWC automated cloud analysis model. AFGWC Tech Memo 78-002, AFGWC, Air Weather Service (MAC), Offutt AFB, NE, 97 pp.

Hadeen, K.D., 1970: AFGWC boundary layer model. AFGWC Tech Memo 70-5, AFGWC, Air Weather Service (MAC), Offutt AFB, NE, 53 pp.

Hayes, J.L., J.E. Hoke, and W.S. Irvine, Jr., 1979: Grids and maps used at the Air Force Global Weather Central. AFGWC Tech Note 79-003 (in preparation).

Jenkins, M., 1978: The AFGWC five layer cloud forecasting model (unpublished manuscript).

Moreno, D., 1973: AFGWC macro-scale upper-air analysis model (Revised). AFGWC Tech Memo 73-1, AFGWC, Air Weather Service (MAC), Offutt AFB, NE, 13 pp.

Palucci, K.J., 1970: AFGWC macro-scale baroclinic prediction model. AFGWC Tech Memo 70-4, AFGWC, Air Weather Service (MAC), Offutt AFB, NE, 11 pp.

Reed, R.J., 1963: Experiments in 1000-mb prognosis. NMC, Weather Bureau, ESSA, Tech Memo 26, U.S. Dept of Commerce, 25 pp.

Shuman, F.G., 1957: Predictive consequence of certain physical inconsistencies in the geostrophic barotropic model. Mon. Wea. Rev., 85, 229-234.

Shuman, F.G., and J.B. Hovermale, 1968: An operational six-layer primitive equation model. J. Appl. Meteor., 7, 525-547.