Observed Long-Period Fluctuations in 500-mb Heights -- Supplementary Text to NCAR Films J-4 and J-6

Roy L. Jenne, Computing Facility, NCAR
John M. Wallace, University of Washington
John A. Young, University of Wisconsin
Eric B. Kraus, University of Miami
PREFACE

Two motion picture films have been produced to show the longer period variations in the 500-mb height fields for the Northern Hemisphere. The two films are called "Daily 500-mb Heights and Long-Period Fluctuations" and "Long-Period Fluctuations in 500-mb Heights." This text has been prepared as an aid in the use of these films. The films were made by using the computer facilities at the National Center for Atmospheric Research.

ACKNOWLEDGMENTS

Our thanks go to Dori Bundy and Dennis Joseph for their able performance of the extensive computer programming required for the preparation of the films. Fred Walden gave helpful support with the technical aspects of the film production. The opportunity for this joint work was made possible by the personnel and facilities of the National Center for Atmospheric Research for which we are appreciative.

October 1973
CONTENTS

Preface ......................................................... iii
Acknowledgments ............................................. iii
Figure Legends ................................................ vii

1. Introduction ............................................... 1
   Film J-4 .................................................. 2
   Film J-6 .................................................. 3

2. Description of Film Highlights ............................ 3
   A. Film J-4 ............................................... 3
   B. Film J-6 ............................................... 6

3. Selected Diagrams Illustrating Filtered Data (15-Day Cutoff) .. 7
   A. Sequential map analyses of low frequency component ........ 7
   B. Time-longitude sections of low frequency component ......... 9
   C. Time-latitude sections of zonally averaged long-period 500-mb height and zonal wind ............... 10
   D. Time-latitude sections of long period 500-mb height fluctuations at particular longitudes .......... 10
   E. Maps of superposed high and low frequency components of 500-mb contours, showing paths of high frequency disturbances ................. 11

Figures ....................................................... 13

Appendices
   1. Technical details for film (J-4): "Daily 500-mb heights and long-period fluctuations"
      A. Film contents ........................................ 57
      B. Data preparation ..................................... 58

   2. Technical details for film (J-6): "Long-period fluctuations in 500-mb heights"
      A. Film contents ........................................ 61
      B. Data preparation ..................................... 62

   3. Available motion pictures produced from the NCAR data bank ........................................ 63

References .................................................. 65
FIGURE LEGENDS

Figures 1.1 and 1.2: Mean January and July 500-mb height fields for the Northern Hemisphere, obtained from Crutcher and Meserve (1970) by time smoothing.

Figures 2.1 through 2.14: Maps of the filtered 500-mb height data each five days for the period 2 July 1969 through 21 August 1970. Periods shorter than 15 days suppressed by filter. Contour interval: 40 m; the heavier contour (with small dots on it) is 5560 m.

Figures 3.1 through 3.11: Longitude versus time cross sections of filtered 500-mb height. Periods shorter than 15 days suppressed by filter. The contour interval is 80 m and the 5600 m contour is darker.

Figures 4.1 through 4.3: Latitude versus time cross sections of filtered zonal mean 500-mb height and zonal wind. Periods shorter than 15 days suppressed by filter. Contour interval: 80 m; the dark line is 5600 m. The geostrophic u-wind has a contour interval of 5 m/sec; the heavy line represents zero, and dashed lines negative (easterly) winds. The geostrophic winds were calculated from a height difference taken over 10° of latitude using the Coriolis parameter at the center latitude. The winds at the two extreme latitudes were calculated by linear extrapolation.

Figures 5.1 through 5.4: Latitude versus time cross sections of filtered 500-mb height for each 30th meridian of longitude for the year that is emphasized (1969-1970). Contour interval: 80 m; the dark line is 5600 m. Figures 5.5 through 5.12 show these data on a reduced scale for the other four years (1966-1969, 1970-1971). Periods shorter than 15 days suppressed by filter.

Figures 6.1 and 6.2: Superposed filtered maps of 500-mb height for 30 January and 10 February, 1970, respectively. Solids lines: low frequency
(periods longer than 15 days) pattern with contour interval = 80 m. Dashed lines: high frequency (periods shorter than 15 days) negative anomaly patterns with contour interval = 40 m. Centers of positive and negative high frequency anomalies are indicated by H and L, respectively.

Figure A1: Amplitude response of the 17-point filter used in this study as a function of the period of the information in the data.
1. INTRODUCTION

Within the past 15 years there have been numerous observational investigations in which the global distribution of one or more atmospheric variables has been separated into components on the basis of various types of spectral decomposition in the space domain. Such studies have provided valuable observational insights concerning the dynamics and energetics of atmospheric disturbances as a function of space scale, and concerning the interactions between the disturbances of different scales. In certain cases the results of these observational studies have been used as a basis for theoretical investigations of the limits of atmospheric predictability.

Up to the present time, there has been a lesser emphasis on spectral decomposition in the time domain. This is due in part to the fact that meteorological time series are quite complicated; "red noise" spectra are prevalent, there being no frequency counterpart to the low-mode cutoff imposed on space fields by the finite size of the earth. In middle latitudes the longer periods are associated mainly with the larger scales of motion (for example, see Kao and Wendell, 1970). Such fluctuations are fundamentally influenced by exchanges of energy and enstrophy between the modes, particularly (but not exclusively) those between the zonally averaged flow and the planetary waves (Yang, 1967; Steinberg, 1971). Theoretical understanding of these long-period exchanges is now meager; it is noteworthy that theories for quasi-two-dimensional "turbulence" yield predictions of spatial spectra but not time spectra.

It follows that the problem of understanding extended range variations (typical periods of a few weeks) remains a major challenge. As a first step there is still a need to describe such flows in a more complete and quantitative manner. Our contribution in this direction has been to produce NCAR films (J-4) and (J-6) entitled: "Daily 500-mb Heights and
Long-Period Fluctuations" and "Long-Period Fluctuations in 500-mb Heights," respectively. These represent attempts to completely portray observed northern hemispheric patterns of extended and longer period activity by utilizing time filtering and the two-dimensional map, time-lapse movie format. In this way it is possible to identify the following features for the longer period systems:

a) the range of space scales (synoptic as well as planetary scales);

b) relationships between various configurations (such as zonal flow, planetary waves, etc.);

c) apparent geographical influences;

d) slow time changes in the fields (seasonal and non-seasonal);

e) the relationships to short-period traveling systems; and

f) anomalies from seasonal "normals."

**FILM J-4**

Most of these features are apparent in film (J-4), which is divided into 3 parts:

1) A one-year unfiltered time-lapse sequence based on twice daily 500 mb maps for the northern hemisphere. (Intermediate frames are interpolated in order to provide smooth time continuity.)

2) A five-year sequence of time-filtered 500-mb maps in which fluctuations with periods shorter than about 15 days have been removed.

3) A one-year sequence showing certain high frequency fluctuations superimposed upon the low frequency ones shown in Part 2.

Some descriptive highlights and figures relating to this film are given in Sections 2 and 3 of this paper. Technical details are discussed in Appendix 1.
FILM J-6

Film (J-6) is divided into five sections:

1) Repeat from film (J-4): a two-year sequence of time-filtered 500-mb maps processed with the 15-day filter cutoff.

2) A four-year sequence of time-filtered maps (30-day cutoff).

3) An eight-year sequence of time-filtered maps (60-day cutoff).

4) A four-year sequence of time-filtered anomalies from the long term "normal" (30-day cutoff).

5) An eight-year sequence of time-filtered anomalies from the long term "normal" (60-day cutoff).

Some features are briefly described in Section 2 of this paper; technical details are discussed in Appendix 2.

2. DESCRIPTION OF FILM HIGHLIGHTS

A. FILM J-4

The first sequence on the film follows the time evolution of the unfiltered 500-mb height field over the course of a year, beginning 1 August 1969. At all seasons, the polar vortex is distorted by wavelike undulations and by closed highs and lows which have their own vortical circulations. Some of these features tend to recur in particular geographical regions, as evidenced by the mean flow patterns shown in Figs. 1.1 and 1.2. For example, during the winter season there is usually a broad trough extending from the coast of China, eastward over Japan and into the Central Pacific. The westerly jet is usually quite strong and quite far south at these longitudes. There is also a trough over the east coast of North America during much of the winter season.

It is evident from the movie that the hemispheric circulation exhibits a great deal of complicated time variability, with the waves and closed
circulations constantly changing in position and intensity. It is apparent that most of the "high frequency" or day-to-day fluctuations are related to the eastward propagation of relatively small scale waves, with typical wavelengths ranging from 2,000 to 10,000 km. These appear to be advected along by the "steering flow" upon which they are superimposed. There are numerous instances in which one can follow the movement of a particular short wave ridge or trough for a week or longer as it propagates eastward in the steering flow.

The steering flow may be thought of as an aggregate of those components of the pattern whose time evolution is not characterized by simple eastward movement. It is made up of the zonally averaged westerly flow, the planetary waves, and the closed or "cutoff" cyclones and anticyclones associated with the so-called "blocking" phenomenon. In general, the time variability of the steering flow seems to be characterized by time scales of several days or longer, in contrast to the eastward propagating short waves, which exhibit noticeable development and movement from one day to the next. The time evolution of this steering flow cannot be described simply.

These impressions are of course, quite subjective. In order to more objectively see the time variability of the 500-mb flow patterns as a function of time scale or frequency we have decomposed it into low and high frequency components by means of the filtering procedure described in Appendix 1.

The second part of the film shows the time evolution of the low frequency component of the flow pattern over a five-year period. The flow patterns are somewhat larger in scale than those in the previous sequence, since it is mainly the short waves that have been removed by the filtering procedure. However, it is clear that the patterns contain much more than just the ultralong waves. The low frequency fluctuations do not show any marked tendency for eastward phase propagation; in fact "retrograde" westward movement seems equally common. Shifts and splits in the jet appear
to be associated with developing features; for example, there is a slight
tendency for major disturbances to radiate outward (southward) from the
polar region. (This is best seen by comparing the appearance of the film
when it is run forward and backward.)

The low frequency fluctuations are hemispheric in scale in the sense
that the transient planetary waves and zonal flow are quite prominent, and
changes in position, orientation and intensity of the associated jet stream
take place nearly simultaneously (on this long time scale) over wide ranges
of longitude. The extent and intensity of the jets are easily identifiable
as dark regions of compressed isolines on the map. Over the course of five
years, the hemispheric flow pattern displays a wide variety of configura-
tions. Apart from the obvious seasonal change, there is little evidence
that certain "favored" patterns tend to re-establish themselves at regular
intervals: qualitatively similar patterns appear to be quite "intermittent."

In addition to viewing the patterns from a global perspective, it is
interesting to attempt to contrast the character of the low frequency time
variability at different longitudes. Significant variability at some lon-
gitudes appears to be associated with blocking activity, but this is prob-
ably not the rule at all longitudes. The longitudinal dependence of low
frequency temporal variance has also been remarked upon by Sawyer (1970).

The final sequence shows the high frequency component of the hemispheric
flow pattern superimposed upon the low frequency component for a period of
one year. From viewing this sequence it is evident that, to a first approx-
imation, the time-smoothed field does indeed act as a steering flow for the
high frequency component. However, it should be borne in mind that the
separation between high and low frequency components is somewhat artificial
in the sense that they are not separated by a real "spectral gap" in the
time domain. Since the low frequency jet flow possesses obvious spatial
structure, there is no significant spectral gap in the space domain either.
Therefore it is not surprising that much of the interaction between the two
components cannot be understood on the basis of a model in which the low
frequency component simply advects the high frequency one. In fact, it is quite likely that the growth and decay of high frequency systems, and not their motion alone, are influenced by such interactions.

B. FILM J-6

The main features of this film relate closely to the long-period flow patterns found in Part 2 of the previous film. In fact, the first part of film (J-6) essentially repeats those patterns, but for a two-year time period instead of five years.

The remainder of this film focuses on somewhat longer period fluctuations: periods shorter than 30 and 60 days are systematically excluded by the filtering. Compared to the maps produced with the 15-day cutoff, variations with periods in the respective ranges 3-4 weeks and 3-8 weeks are thus absent. It follows that these patterns are not influenced by isolated vortical circulations persisting for a week or so, in possible contrast to those for the 15-day filter. The patterns continue to reflect the smoothly varying seasonal changes and the planetary-scale anomalies which produce inter-annual differences for a given season. Differences in seasonal evolutions between years become more apparent because the time-lapse rate is speeded up and the total number of years is increased. Thus, the patterns with 30 (60) day filter cutoffs are shown for 4 (8) years at a rate of 12 (24) days per second of film time (at 24 frames/sec).

The final two parts of the film portray the patterns in terms of the long period anomalies from seasonally varying climatological "normals." The use of anomaly fields has become a standard technique for representing deviations of weather patterns on an "extended range" time scale. In the present application, the film allows examination of the continuous time evolution of these anomalies, and so is an improvement over individual static displays.
The long-period anomalies also represent a different perspective from the total long-period patterns. This is so because the climatological "normal" field is essentially a "predictable" one, and its elimination means that the anomalies contain modes with limited predictability. Calculation of the anomalies also removes a major amount of variance at periods of one year or less, so that the spectrum of the anomalies is peaked at periods between the cutoffs (30 or 60 days) and one year (365 days).

The film shows that the anomalies are commonly of the planetary and larger synoptic scales. Their time behavior is quite erratic: (a) centers seem to form and expand without great movement, suggesting direct or indirect geographical influence; (b) once developed, they shift location by distances comparable to the associated "wavelength" before vanishing; (c) their longitudinal component of motion may be eastward or westward, but is often predominately one or the other; (d) their meridional component is generally considerable, with frequent cross-polar motion; and (e) the centers lose identity by decaying or merging with other centers.

3. SELECTED DIAGRAMS ILLUSTRATING FILTERED DATA (15-DAY CUTOFF)

This section presents diagrams of filtered data with a 15-day cutoff used to make Film J-4.

A. SEQUENTIAL MAP ANALYSES OF LOW FREQUENCY COMPONENT

Figures 2.1 through 2.14 are map excerpts at five-day intervals taken from Part 2 of film (J-4) for the period 2 July 1969-21 August 1970. The filter cutoff is 15 days, the contour interval is 40 m and the heavier contour is 5560 m.

These "snap shots" illustrate many of the film features described in the previous section. They are useful for studying the time evolution of

---

1 Microfilm copies for the entire period 3 July 1966-27 June 1971 are on file at NCAR.
individual disturbances from map to map. Sequential sampling of maps from successive figures gives a feel for seasonal changes. From an inspection of these diagrams it is evident that some individual systems appear to have long lifetimes. This occurs because the faster changing high frequency components have been filtered out and the normal climatological features tend to add an element of geographical persistence. The tracking of centers appears particularly easy for closed cyclones. For example, the low center near the pole on 2 July 1969 can be followed until late August when its vorticity center finally drifts southward into the eastern Pacific.

The summer seasons are marked by numerous closed cyclones and anticyclones which exhibit a wide variety of space and time scales. The split jets common with well developed waves during the winter are more persistent during May when the subtropical and polar jets are separated but strong. Some of the centers are quite long lived during summer. For example, a short wave ridge which first appears over northern Europe on 17 July 1969 persists for about a month, during which time it develops into a closed anticyclone over Scandinavia. This period is in strong contrast to the month of July 1970 during which a cyclonic circulation prevailed over most of Europe.

The winter circulation is dominated by the strong westerly jet stream and the planetary waves. For example, around 1 December 1969 wave number 4 appears dominant in the hemispheric circulation, while the period around 28 January 1970 is marked by a strong wave number 2 component at the higher latitudes. The climatological features (notably the troughs over the western oceans) are almost always evident, but there does not appear to be any simple way to characterize the time evolution of the transient patterns.

Examples of strong or persistent ridging in the figures include:

Europe: 17 July-16 August 1969, 30 September-20 October 1969, 7 June-2 July 1970

Asia: 20 September-5 October 1969, 14 November-14 December 1969, 17 June-1 August 1970


B. TIME-LONGITUDE SECTIONS OF THE LOW FREQUENCY COMPONENT

Figures 3.1-3.11 provide a convenient means for analyzing the zonal displacements and developments of low frequency disturbances along latitude circles 60°N, 45°N, and 30°N.

Diagrams 3.1-3.6 show consecutive four-month time sections during the period July 1969-October 1970 for each of the three latitudes. Fields for three consecutive years (July 1966-June 1967, July 1967-June 1968, and July 1968-June 1969) are portrayed in diagrams 3.7-3.11 (a fourth year is given for 45°N). These diagrams allow comparisons between different latitudes, seasons, and years to be easily made.

It should be remembered that each field contains a normal trough and ridge pattern which is geographically anchored and changes only on a seasonal time scale; the fluctuating anomalies which are superimposed are free to move and account for most "tilting" patterns on the longitude-time sections. Note that on most diagrams these low frequency patterns show little inclination for a well defined tilt. There is a rather striking westward propagation evident at 60°N during the winter of 1967-68.

However, this behavior is not found at 45°N, where an alternating sequence of anomalies drifts slowly eastward across the Pacific at the same
time. During the autumn of 1967 the patterns at 60°N appear to drift eastward.

The mean climatological features are evident in these diagrams, particularly during the winter seasons at 45°N. At this latitude, one can also see the tendency for blocking highs to form during the winter months near the west coasts of the continents (0° and 230°E).

C. TIME-LATITUDE SECTIONS OF ZONALLY AVERAGED LONG-PERIOD 500 MB HEIGHT AND ZONAL WIND

Figures 4.1-4.3 show the variation of filtered zonally averaged heights and zonal flow as a function of latitude and time for five consecutive years. Except for the seasonal variation, the low frequency variability of zonally averaged 500-mb height is much smaller than the variability at individual longitudes (shown next in Subsection D). The associated variations of zonally averaged geostrophic wind are on the order of 5-10 m sec\(^{-1}\) at middle latitudes.

Each year possesses an obvious seasonal change in the zonal flow distribution. Superimposed upon this are fluctuations which reflect changes in intensity and latitude of the zonally averaged jet. These fluctuations vary from one year to the next, and are occasionally pronounced, as in the winter of 1967-1968. Significant coupling between latitudes is apparent, as evidenced by the breadth of extrema and the tilted-line "propagation" between latitudes. These variations correspond to those traditionally defined as "index cycles," but we note that they are quite irregular, rather than quasi-periodic.

D. TIME-LATITUDE SECTIONS OF LONG PERIOD 500-MB HEIGHT FLUCTUATIONS AT PARTICULAR LONGITUDES

Figures 5.1-5.12 show the long period 500-mb height variability as a function of time and latitude along a given meridian. The differences between these figures and the preceding ones for zonally averaged heights
are due to the inclusion of zonal deviations. These deviations are due to (a) "planetary" waves which are mainly stationary but undergo seasonal changes in position and intensity, and (b) planetary and larger synoptic-scale systems which fluctuate strongly within a given season and account for much of the complicated variability noted earlier in Subsections (A) and (B).

The patterns shown here reflect latitudinal excursions of pressure systems which have developed locally or have moved from another longitude. Local troughing and ridging are thus clearly indicated, along with latitudinal displacements of the jet. These local displacements are highly variable and sometimes very sudden (as viewed on this time scale); when they are longitudinally extensive they represent a "cycle" in local zonal flow intensity which is much stronger and more variable than that for the zonally averaged flow (Subsection C).

At most longitudes the majority of the undulations display a slight tilt, so that individual disturbances appear first at the higher latitudes and slightly later at the lower latitudes. However, it may be noted that there are numerous cases in which the apparent propagation of individual systems is northward, rather than southward.

It is very interesting to compare the sections for different longitudes. For example, the sections for longitudes corresponding to the western oceans exhibit less extreme excursions of the 5600 m contour than do the sections for the eastern oceans (compare, for example, 150°E vs. 150°W). Many other comparisons suggest themselves, including comparison of the longitudinal differences on a year-by-year basis (one year of diagrams is shown in Figs. 5.1-5.4; four years are shown in 5.5-5.12).

E. MAPS OF SUPERPOSED HIGH AND LOW FREQUENCY COMPONENTS OF 500-MB CONTOURS, SHOWING PATHS OF HIGH FREQUENCY DISTURBANCES

Figures 6.1 and 6.2 are excerpted from Part 3 of film J-4. The long-period fields (with a 15-day filter cutoff) are shown in solid lines, and
instantaneous high frequency low pressure anomalies are dashed lines (high pressure anomalies are not given). From this information it would be possible to construct the total instantaneous field in the vicinity of low pressure anomalies by addition. For example, dashed centers would produce deepened troughs or flattened ridges when added to the solid pattern, depending upon the relative locations. In the two examples given, it appears that the long-period ridges are relatively free of short-period height reductions.

Since the long-period fields are a strong flow feature at all locations, it follows that they must produce a significant advective effect. The tracks on these diagrams (shown by successive 12-hourly positions of centers) indicate that the long-period flow does in fact "steer" the short-period disturbances. Systematic deviations of the tracks from the long-period contours may be due to the motion of the long period systems, nonlinear effects, or the influence of unsteady divergence fields.
Fig 1.1 Mean January 500-mb height for the Northern Hemisphere, obtained from Crutcher and Meserve (1970) by time smoothing.
Fig 1.2 Mean July 500-mb height for the Northern Hemisphere, obtained from Crutcher and Meserve (1970) by time smoothing.
Fig 2.1 Figures 2.1 through 2.14 are maps of the filtered 500-mb height data each five days for the period 2 July 1969 through 21 August 1970. Periods shorter than 15 days suppressed by filter. Contour interval: 40 m; the heavier contour (with small dots on it) is 5560 m.
Fig 2.2
Fig 2.4
Fig 2.5
Fig 2.6
Fig 2.7
Fig 2.8
Fig 2.9
Fig 2.11
Fig 2.12
Fig 2.13
Fig 2.14
Fig 3.1 Figures 3.1 through 3.11 are longitude versus time cross sections of filtered 500-mb height. Periods shorter than 15 days suppressed by filter. The contour interval is 80 m and the 5600 m contour is darker.
500 mb height (periods longer than 15 days)
longitude vs time plots for a latitude
march 1970 - june 1970

500 mb height (periods longer than 15 days)
longitude vs time plots for a latitude
july 1970 - october 1970

Fig 3.2
500 mb height (periods longer than 15 days) longitude vs time plots for a latitude
july 1969 - october 1969

45N

months

0 90E 180E 270E 360E

Fig 3.3

500 mb height (periods longer than 15 days) longitude vs time plots for a latitude
november 1969 - february 1970

45N

months

0 90E 180E 270E 360E
500 mb height (periods longer than 15 days) longitude vs time plots for a latitude
march 1970 – june 1970

Fig 3.4

500 mb height (periods longer than 15 days) longitude vs time plots for a latitude
july 1970 – october 1970

Fig 3.4
500 mb height (periods longer than 15 days)
longitude vs time plots for a latitude
july 1969 - october 1969

500 mb height (periods longer than 15 days)
longitude vs time plots for a latitude
november 1969 - february 1970

Fig 3.5
Fig 3.6
Fig 3.7
500 mb height (periods longer than 15 days)
longitude vs time plots for a latitude
july 1966 october 1966

Figure 3.8
FIG 3.9
500 mb height (periods longer than 15 days)
longitude vs time plots for a latitude
july 1968 - october 1968

500 mb height (periods longer than 15 days)
longitude vs time plots for a latitude
july 1968 - october 1968

Fig 3.10
500 mb height (periods longer than 15 days)
longitude vs time plots for a latitude
July 1968 - October 1968

Figure 3.11
500 mb height (periods longer than 15 days) latitude vs time plots for a longitude july 1969 - june 1970

**ZONAL MEAN**

Fig 4.1 Figures 4.1 through 4.3 are latitude versus time cross sections of filtered zonal mean 500-mb height and zonal wind. Periods shorter than 15 days suppressed by filter. Contour interval: 80 m; the dark line is 5600 m. The geostrophic u-wind has a contour interval of 5 m/sec; the heavy line represents zero, and dashed lines negative (easterly) winds. The geostrophic winds were calculated from a height difference taken over 10° of latitude using the Coriolis parameter at the center latitude. The winds at the two extreme latitudes were calculated by linear extrapolation.
500 mb height (periods longer than 15 days) latitude vs time plots for a longitude
july 1966 - june 1967

ZONAL MEAN

zonal mean geostrophic u-wind (m/sec)

july 1967 - june 1968

ZONAL MEAN

zonal mean geostrophic u-wind (m/sec)

Fig 4.2
500 mb height (periods longer than 15 days) latitude vs time plots for a longitude
july 1968 - june 1969 ZONAL MEAN

ZONAL MEAN

zonal mean geostrophic u–wind (m/sec)

july 1970 - june 1971 ZONAL MEAN

zonal mean geostrophic u–wind (m/sec)

Fig 4.3
500 mb height (periods longer than 15 days) 
latitude vs time plots for a longitude 
july 1969 - june 1970

Fig 5.1 Figures 5.1 through 5.4 are latitude versus time cross sections of filtered 500-mb height for each 30th meridian of longitude for the year that is emphasized (1969-1970). Contour interval: 80 m; the dark line is 5600 m. Figures 5.5 through 5.12 show these data on a reduced scale for the other four years (1966-1969, 1970-1971). Periods shorter than 15 days suppressed by filter.
500 mb height (periods longer than 15 days) latitude vs time plots for a longitude july 1969 – june 1970

Fig 5.2
500 mb height (periods longer than 15 days) latitude vs time plots for a longitude
july 1969 - june 1970

Fig 5.3
500 mb height (periods longer than 15 days) 
latitude vs time plots for a longitude 
july 1969 - june 1970
500 mb height (periods longer than 15 days) latitude vs time plots for a longitude July 1966 - June 1967.

**Fig 5.5**
500 mb height (periods longer than 15 days) latitude vs time plots for a longitude july 1966 - june 1967

Figure 5.6
500 mb height (periods longer than 15 days) latitude vs time plots for a longitude July 1967 - June 1968

Fig 5.7
500 mb height (periods longer than 15 days)
latitude vs time plots for a longitude
july 1967 - june 1968

Fig 5.8
500 mb height (periods longer than 15 days) 
latitude vs time plots for a longitude 
july 1968 - june 1969

Fig 5.9
500 mb height (periods longer than 15 days)
latitude vs time plots for a longitude
july 1968 – june 1969

Fig 5.10
500 mb height (periods longer than 15 days)
latitude vs time plots for a longitude
july 1970 - june 1971

Fig 5.11
500 mb height (periods longer than 15 days)
latitude vs time plots for a longitude
july 1970 – june 1971

**Fig 5.12**
Fig 6.1  Figures 6.1 and 6.2 show superposed filtered maps of 500-mb height for 30 January and 10 February, 1970, respectively. Solid lines: low frequency (periods longer than 15 days) pattern with contour interval = 80 m. Dashed lines: high frequency (periods shorter than 15 days) negative anomaly patterns with contour interval = 40 m. Centers of positive and negative high frequency anomalies are indicated by H and L respectively. Dots show the positions of successive 12-hourly anomaly centers. A small 2 by a dot means two days after this map time.
A. FILM CONTENTS

The total running time of the film (including the titles) is 12 min 47 sec at 24 frames/sec. The black and white 16-mm film is about 450 ft in length.

The contents of the three sections are as follows:

1) Unfiltered sequence of twice daily 500-mb maps: 1 August 1969-30 July 1970; 10 frames per day. (Frames between 12-hourly map times are constructed from grid data that were linearly interpolated in time.) Contour interval: 80 m. Running time: 152 sec.

2) Time-filtered 500-mb analyses (15-day cutoff) 1 July 1966-30 June 1971; 3.5 frames per day. Filtering removes fluctuations with periods shorter than about 15 days. Filtered values are produced every 48 hr, with intermediate times linearly interpolated. Contour interval: 40 m. Running time: 266 sec.

3) High frequency fluctuations superimposed upon the time-smoothed analyses shown in Part 2 (15-day cutoff): 1 August 1969-30 July 1970 (dates identical to those in Part 1); 14 frames per day. High frequency maps are formed by subtracting time-smoothed analyses of Part 2 from original ones at each movie frame time. High frequency component is indicated by dashed lines with 40-m contour interval, shown only for negative values (where instantaneous 500-mb height is lower than the time-smoothed one). Most letters "H" and "L" denote instantaneous positions of positive and negative extrema of the high frequency component. Low frequency (time-smoothed) component is indicated by solid lines with 80-m contour interval. Running time: 213 sec.
B. DATA PREPARATION

The film is based on 8 years of 500 mb height analyses prepared every 12 hours at the National Meteorological Center (NMC). These analyses were usually based on the NMC "Final Run," which often included data received up to 10 hours after the observation time. They were archived on the NMC 1977-point octagonal grid. For this project these data were subsequently transferred to a grid consisting of 5° latitude and longitude intersections extending from 20°N to the pole. The transformation was accomplished using a 16-point interpolation program. The film was prepared from these interpolated grid-point data. Whenever a map was missing in this archive, one was constructed by means of linear interpolation in the time domain. The only significant missing periods were 20-25 July 1967, 28-31 July 1968, 30 August-20 September 1968 (one map was available, 4 Sept.), and 28-31 October 1968.

The low-pass filtered (or time smoothed) analyses for Parts 2 and 3 of the film were generated by first making a tape consisting of 2-day average maps produced at 2-day intervals. These averages were based on four successive, individual maps; thus for each grid point

$$\overline{Z}(t_i) = \frac{1}{4} [Z(t_i - 18) + Z(t_i - 06) + Z(t_i + 06) + Z(t_i + 18)]$$

where $\overline{Z}(t_i)$ is the 2 day average geopotential height centered at time $t_i$ (expressed in hours). Next, the 17-point low-pass filter described in Fig. A1 was applied to the 2-day averages (which appeared at 2-day intervals) to compute the time-filtered geopotential heights

$$\hat{Z}(t_i) = \omega_0 \overline{Z}(t_i) + \sum_{j=1}^{8} \omega_j [ \overline{Z}(t_i + 48j) + \overline{Z}(t_i - 48j) ]$$

where the $\omega_j$ are the weights of the filter. This procedure generated filtered geopotential heights at 2-day intervals. Values for intermediate film times were then obtained by linear interpolation in the time domain.
The amplitude response of the filter for various frequencies is shown in Figure Al. (In the present application note that "$\Delta t$" corresponds to two days.) It is readily seen that the filter has virtually no effect on fluctuations with periods longer than 20 days, while it nearly completely removes those with periods shorter than 10 days.

The high-pass filtered analyses for Part 3 of the film were generated at each frame time by subtracting the interpolated values of the low-pass filtered geopotential height from the unfiltered value (interpolated linearly between 12-hourly analyses) at each grid point; i.e.

$$Z^* (t) = Z (t) - \hat{Z} (t)$$

where $Z^*(t)$ is the high-pass filtered geopotential height at frame time $t$. Computer contouring for the film utilized linear interpolation between the 5° latitude-longitude grid points.
Fig A1  Amplitude response of a 17-point filter as a function of the period of information (in grid units) in the data. The amplitude response is given by the ratio of the initial amplitude to the final amplitude after filtering. The weighting coefficients are for 17 data points in one time or space direction where $W_0$ is the weight for the center point. After Bleck (1970).
A. FILM CONTENTS

The total running time of the film (including the titles) is 11 min at 24 frames sec. The black and white 16-mm film is about 400 ft in length.

The contents of the five sections are as follows:

1) Time-filtered 500-mb analyses (periods longer than 15 days are shown): 1 July 1969-30 June 1971; 3.5 frames/day. As in film (J-4), filter cutoff is at approximately 15 days; filtered values are produced every 48 hours, with intermediate times linearly interpolated. Contour interval: 40 m (the heaviest contour is 5560 m). Running time: 106 sec.


4) Anomalies of time-filtered 500-mb analyses (30-day cutoff) from climatological "normal": 1 July 1967-30 June 1971; 2 frames/day. Contour interval: 40 m. Running time: 120 sec.

B. DATA PREPARATION

The basic data were the same as in film (J-4) (Appendix 1). The filtered values with a 15-day cutoff (Part 1) were taken from film (J-4): the original procedures are outlined in Appendix 1. The 30-day filtered data (Parts 2 and 4 of the film) were prepared by applying the 17-point filter shown in Appendix 1 to each grid point for 17 successive non-overlapping maps, where each map was the average of four days of data (corresponding to eight original 12-hourly values). Similarly, the 60-day cutoff data (Parts 3 and 5) was obtained by applying the 17-point filter to eight-day averages.

Anomalies for the filtered data were calculated by subtracting long-period monthly climatological "normal" values from the filtered values. The climatological values were obtained for each frame time by linear interpolation of the monthly means produced by Crutcher and Meserve (1970) and Crutcher and Jenne (1969).
APPENDIX 3

AVAILABLE MOTION PICTURES PRODUCED
FROM THE NCAR DATA BANK

The following 16-mm motion pictures have been made to support research and educational goals at NCAR and the universities. These were produced using the NCAR computer data base and 35-mm computer microfilm facilities.

J-1 A Selected Climatology of the Southern Hemisphere. Shows the change of the monthly mean climatology through the year (surface-100 mb). Includes temperature--dewpoint spread for the surface through 500 mb. Includes some Northern Hemisphere data for comparison. Has one year of daily 500-mb maps from each hemisphere. Black and white, silent; 29 min at 16 frames/sec. (NCAR 1969). A supplementary text is available (Van Loon and Jenne, 1970).


J-4 Daily 500-mb Heights and Long Period Fluctuations. Northern Hemisphere. (a): 12-hourly height maps (with interpolated frames) for 1 August 1969 to 30 July 1970. The movement of the pressure systems is very smooth. (b): Filtered maps for 1 July 1966 to 30 June 1971. (Periods longer than 15 days shown.) (c): Twice-daily 500-mb low pressure anomalies are superimposed on the 15-day time

J-5 A Selected Climatology of the Northern Stratosphere. 100 mb to 10 mb. Black and white, silent; 12 min at 24 frames/sec. (NCAR 1972).

J-6 Long Period Fluctuations in 500-mb Heights. Northern Hemisphere. Time-filtered data for 1 July 1969 to 30 June 1971 (periods longer than 15 days), 1 July 1967 to 30 June 1971 (periods longer than 30 days), 1 July 1963 to 30 June 1971 (periods longer than 60 days). Finally, time-filtered anomalies from the climatological "normal" are given for the latter two cases. Black and white, silent; 11 min at 24 frames/sec. (NCAR 1973).

To obtain a copy of these films (or magnetic tapes of the basic data) write to

Mr. Roy L. Jenne
National Center for Atmospheric Research
P.O. Box 1470
Boulder, Colorado 80302

Payment may be made in advance (payable to the National Center for Atmospheric Research) or a bill can be sent. The following prices are subject to change without notice:

<table>
<thead>
<tr>
<th>Film</th>
<th>Surface Mail</th>
<th>Air U.S. and Canada</th>
<th>Air Overseas at Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>J-1</td>
<td>$38.00</td>
<td>$40.00</td>
<td>~ $48.00</td>
</tr>
<tr>
<td>J-2</td>
<td>20.00</td>
<td>21.00</td>
<td>~ 24.50</td>
</tr>
<tr>
<td>J-3</td>
<td>20.00</td>
<td>21.00</td>
<td>~ 24.50</td>
</tr>
<tr>
<td>J-4</td>
<td>25.00</td>
<td>26.00</td>
<td>~ 30.00</td>
</tr>
<tr>
<td>J-5</td>
<td>24.00</td>
<td>25.00</td>
<td>~ 29.00</td>
</tr>
<tr>
<td>J-6</td>
<td>23.00</td>
<td>24.00</td>
<td>~ 28.00</td>
</tr>
<tr>
<td>Supplementary text</td>
<td>No Charge</td>
<td>No Charge</td>
<td>No Charge</td>
</tr>
</tbody>
</table>
REFERENCES

Bleck, R., 1970: Personal communication.


