NHC

CLIMATE ANALYSIS CENTER

FY 1990

ANNUAL REPORT

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
National Meteorological Center

CLIMATE ANALYSIS CENTER
FY 1990
ANNUAL REPORT

TECHNICAL EDITOR: L. P. MANNELLO

January 1991

U. S. DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL WEATHER SERVICE

NATIONAL METEOROLOGICAL CENTER

TABLE OF CONTENTS

STAFF OF THE CLIMATE ANALYSIS CENTER

OFFICE OF THE DIRECTOR
Director, D. R. Rodenhuis
Secretary, G. S. Lucas

E. S. Epstein
A. L. Leetmaa
L. P. Mannello
E. C. Michaelides

PREDICTION BRANCH
Chief H. M. van den Dool[1]
Secretary, V. Mershon

J. Anderson[2]
A. Artusa
A. G. Barnston
W- Y. Chen
W. Ebisuzaki[3]
J. Feng[2]
J. Hoopingarner
F. D. Hughes
R. E. Livezey
E. A. O'Lenic
R. Schechter
M. S. Tracton
A. J. Wagner

DIAGNOSTICS BRANCH
Chief, C. F. Ropelewski
Secretary, P. Davis

J. D. Bell
M. Chelliah[3]
D. B. Davidowicz
D. R. Garrett
M. S. Halpert
J. E. Janowiak
M. Ji[3]
J. D. Kopman
V. E. Kousky
A. Kumar[3]
T. Lee[3]
D. C. Marsico
K. C. Mo
E. M. Rasmusson[4]
R. W. Reynolds
H. Rui[3]
T. Smith[2]
J. Wang[3]
K. Ward[3]

ANALYSIS & INFORMATION BRANCH
Chief, J. D. Laver
Secretary, A. C. Kellar

N. L. Canfield[4]
R. H. Churchill
J. M. Dionne
G. G. Fulwood
M. E. Gelman
J. Harrison
A. Herman[3]
R. Holasek[3]
D. Kann
S. Katz[3]
M. Knezevic
R. L. Lehman
A. J. Miller
D. Miskus
R. M. Nagatani
E. Ongurer[3]
V. L. Patterson
P. Sabol
L. K. Thomas
R. J. Tinker
S- K. Yang[3]

AGRICULTURAL WEATHER SECTION
Chief, D. M. LeComte
Secretary, J. Houston

V. Bjerknes
O. W. Byrd
T. R. Heddinghaus
R. Stefanski

---

1. Intergovernmental Personnel Apointment
2. Visiting Scientist
3. Contractor
4. Research Associate, CICS

EXECUTIVE SUMMARY

The increasing awareness of global change issues has added another dimension to the climate information, monitoring, and prediction programs of the Climate Analysis Center.

CLIMATE INFORMATION - A new publication was produced in collaboration with the National Climatic Data Center/NESDIS. It is entitled: Climate Assessment for 1989 - Selected Indicators of Global Climate. Plans are being developed to expand this publication with information from other organizations to increase our monitoring of climate impacts. Two other relatively new climate and weather publications have received the attention of NOAA--the Weather and Climate Update, a weekly summary for the U.S.; and PRESTO, a monthly summary of local climate anomalies. In addition, CAC scientists had 75 articles published and made 44 presentations at formal scientific meetings during the year.

The Climate Dial-Up Service (part of the NWS Family of Services) now has more than 300 subscribers and supports access to national and international networks. Also, A new electronic connection to the Joint Agricultural Weather Facility (JAWF) at the USDA has greatly improved the availablity of products for crop assessment. A complete list of CAC products follows this summary.

CLIMATE MONITORING - The core of the climate monitoring program is the detection of global climate anomalies on the time scale of weeks to years. Current attention is directed to the equatorial Pacific where the cold phase of the ENSO has evolved towards higher sea surface temperatures and related indices of pressure, surface winds, and convection. The CAC has issued 7 ENSO Advisories, and continues to monitor oceanic and atmospheric indices for the possible development of a warm ENSO event in the coming year.

A numerical model of the Tropical Pacific Ocean is currently used to assimilate sparse oceanic observations for the assessment of ENSO oceanic conditions. This is an important and unique component in our monitoring program and is a prerequisite for developing a prediction capability by numerical methods. Also, a new higher resolution SST analysis has been produced using the optimum interpolation method. These daily SST analyses will be used to support the operational ocean modeling effort and to the specify the lower boundary conditions for the MRF model.

The CAC is developing a program for global climate monitoring using remote-sensing data . Current products include: out-going long wave radiation, global precipitation, sea surface temperatures, and ozone analyses and trends. The new challenge is to use these data to detect trends in climate indices as well as temporal and spatial variations. This will be our contribution to the WMO/Climate Change Detection Project. In particular, indices, based on AVHRR data, were used to identify a record minimum (since 1965) in NH snow cover. Also, a 5-year data set of Vegetation Index (VI) was constructed from AVHRR data to help detect anomalies and trends in the surface vegetation. Video cassettes of VI, SST, precipitation, and a drought index were prepared for the upcoming WMO/Second World Climate Conference and a briefing for the NOAA Administrator.

CLIMATE PREDICTION - One of the most challenging situations faced by CAC/ Prediction Branch forecasters was the U.S. seasonal temperature forecast for the 1989-90 winter. This forecast was accurate in the populous eastern United States, which experienced one of the coldest Decembers on record, yet the

December 1989-February 1990 period was above normal overall. Both of these events were correctly predicted. This guidance was presented at an emergency meeting of energy decision-makers, called by the U.S. Department of Energy on December 23, 1989 at the height of the cold outbreak. The operational prediction program has been improved by automating present forecast procedures so that a full scope of forecast tools are available to 6-10 day, 30-day, and 90-day forecasters.

New methods are being investigated to develop numerical products for CAC's Monthly and Seasonal Outlooks. CAC scientists participated in an international workshop at NCAR and are collaborating in a number of NOAA-wide efforts (e.g., the DERF Project). CAC now publishes its own empirical ENSO forecast along with two extramural forecast results (Cane; O'Brien) in its Climate Diagnostics Bulletin. For the first time, a coupled (tropical) model has been run on the NMC computer. Our long-term goal is to use an ocean/atmosphere coupled model for ENSO prediction.

Special efforts are also underway at CAC to study global climate events that have social and economic impact. These include: the cause of the 1988 U.S. drought, the numerical simulation of the Asian Monsoon, and the development of a program to monitor and predict African climate anomalies.

NATIONAL PROGRAMS - As part of NOAA's operating plan, a Climate Services Management Council was formed with inter-NOAA participation. They have met and commissioned a "NOAA Climate Services Plan" which describes the vision in climate services in the next decade. The CAC is collaborating with the NCDC on the development of this Plan. In the NOAA research effort, the CAC is a participant in a number of projects under the NOAA Climate and Global Change Program. These include: Ozone (with ERL), Vegetation Index (with NESDIS), Climate Data Assimilation System (with NMC), Diagnostics (with ERL), Perspectives (with NCDC), and Global Precipitation Climatology Project (WMO/WCRP sponsorship). In addition, preparations have been made for three new projects which will take us into the next decade. They are: Dynamical Extended-Range Forecast (with NMC/Development Division, NOAA/GFDL and ERL/Climate Research Division), Regional Climate Centers Programs, and Data Management.

INTERNATIONAL ACTIVITIES - The global nature of climate continues to influence our international activities. CAC personnel actively participated in the U.S./USSR bilateral agreement with working visits to Moscow; in the U.S./Brazil bilateral agreement with the visit of 4 Brazilian scientists, the organization of a Numerical Weather Prediction Workshop and in the development of the NMC South American desk. Other contributions were made to the IPCC and to the WMO/World Climate Program, especially in the Climate Change Detection Project, Global Precipitation Climatology Project, and for the Global Energy and Water Experiment (GEWEX). Participation continues in both the TOGA and EPOCS Projects, the International Ozone Commission, and the AID/Famine Early Warning System (FEWS). CAC staff also participated in the activities of the WMO Commission on Climatology, the Commission on the Atmospheric Sciences, and the World Climate Research Program.

I would like to conclude this Summary with an acknowledgement to the entire CAC staff for making the above accomplishments possible.

David R. Rodenhuis
Director, CAC

CAC Products

Weekly Climate Bulletin
Special Climate Bulletins
Drought Advisories
Climate Dial-up Service
Output File for FAX, teletype, AFOS
Public Information
Daily Weather Maps

Weekly Weather and Crop Bulletin
Special Agriculture Bulletins
Weekly Agriculture Assessment Briefings

Global Height Analyses (70 - 0.4 mb)
Global Ozone Analyses (30 - 0.4 mb)

Climate Diagnostics Bulletin
Monthly Global Atmospheric and
    Oceanic Analyses
ENSO Advisories
Seasonal Review Article (JOC)

Medium Range Outlook (6-10 day)
Monthly Outlook (semi-monthly)
Seasonal Outlook (monthly)

Climate Diagnostics Workshop (annual)

THIS PAGE INTENTIONALLY LEFT BLANK

1. CLIMATE DIAGNOSTICS

1.1 Tropical Ocean-Atmosphere Interaction

1.1.1 Tropical Surface and Momentum Fluxes (Reynolds, Marsico)

Tropical Pacific surface winds from the PMEL buoys have been inserted into the NMC surface analyses and the Medium-Range Forecast (MRF) model since March 1990. Techniques have been developed to monitor the difference between the surface winds from the MRF and the buoy winds. Weekly statistics (means, standard deviations and rms differences) are now computed between the two types of winds at the buoy locations and are being sent to PMEL, so that the accuracy of the buoy winds can be maintained. Figure 1 shows a progressive vector comparison between the NMC/MRF winds and the buoy winds at 5^{o}N and 110^{o}W. During the first month and a half, both winds were mainly zonal, although the MRF winds were noticeably weaker. After this period, the meridional components became larger and the directions also differed. At other locations and times, the zonal components tend to agree better than the meridional components. The agreement between the modeled winds and the buoy winds also tends to be better in areas with smoothly varying wind fields, i.e., in regions in the middle of the southeast and northeast trades.

1.1.2 Ocean-Atmosphere Coupling (Kousky)

The primary goal of this research is to develop an understanding of the evolution of the Southern Oscillation in the ocean/atmosphere coupled system. Toward this goal, a study was performed to relate sea surface temperature (SST) anomalies with mid-tropospheric (500 mb) temperature and upper tropospheric geopotential height anomalies. Results indicate that the 500 mb temperature anomalies, either zonally-averaged or regionally-averaged in the tropics, lag the SST anomalies in the central equatorial Pacific by three to five months (figure 2). The results for 200 mb heights are similar (figure 3). The lag between upper tropospheric height and SST anomalies increases from the tropics to the subtropics, with subtropical latitudes lagging the tropics by six to ten months (figure 4).

This lagged relationship suggests that even though tropical sea surface temperatures return to near normal, the atmospheric circulation anomalies characteristic of previous warm or cold episodes linger on. Also, as the heating associated with a warm episode spreads to subtropical latitudes, it may serve to amplify mid-latitude upper level ridges and contribute to persistent anomalies at these latitudes. For example, the anomalously strong and persistent upper-level ridge, which developed over North America during Spring 1988, may have been amplified by the existence of the abnormally warm subtropical latitudes that resulted from the previous warm episode. However, the correlation analysis and recent studies reveal that the mid-latitude anomaly patterns over North America are not consistent from one warm (or cold) episode to the next. The results were presented at a Drought Workshop (University of Maryland) and will be included in a paper for the upcoming Meeting of the VI Brazilian Meteorological Congress (November 1990).

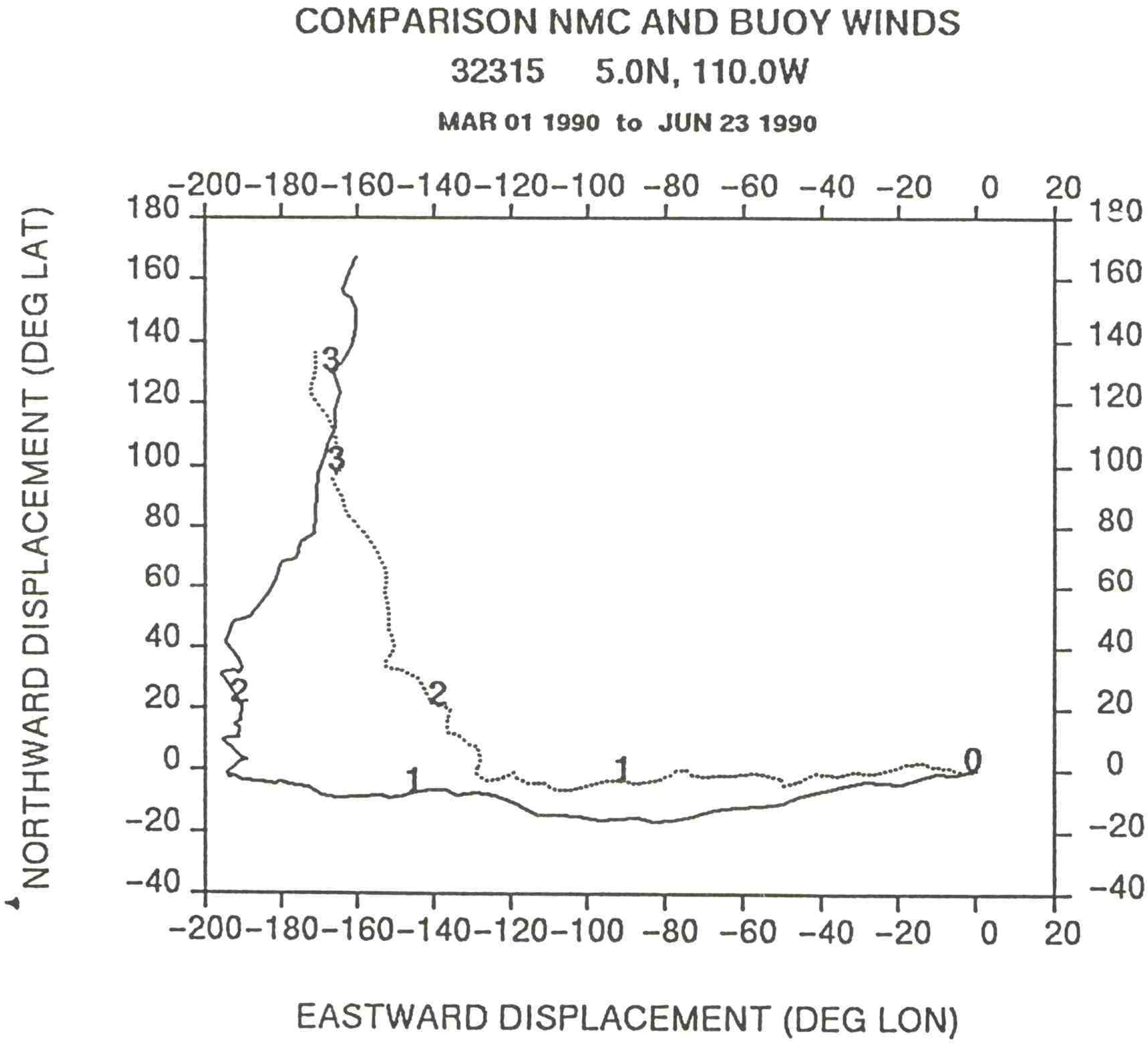


Figure 1 Daily progressive vector diagram for surface winds from the NMC forecast model (solid curve) and the TOGA Tropical Atmosphere/Ocean mooring (dotted curve) at 5°N, 110°W. The period of record is March 1 through June 23, 1990. The numbers on the curves indicate the number of 30 day periods relative to "0" which is the starting point of the record.

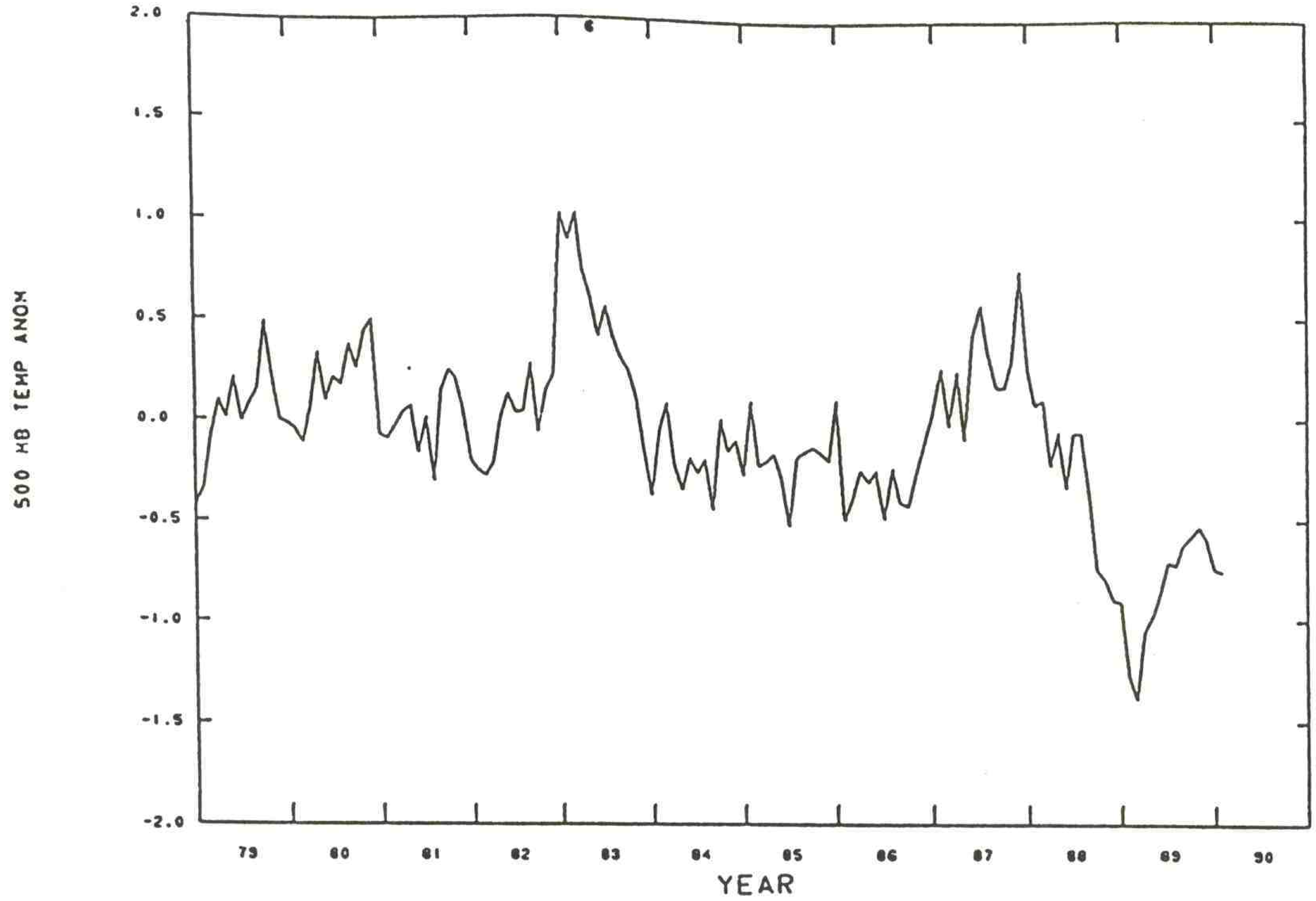


Figure 2 Time series of zonally-averaged monthly 500-mb temperature anomalies for 20°N-20°S. Anomalies (°C) are computed with respect to the 1979-1988 base-period means.

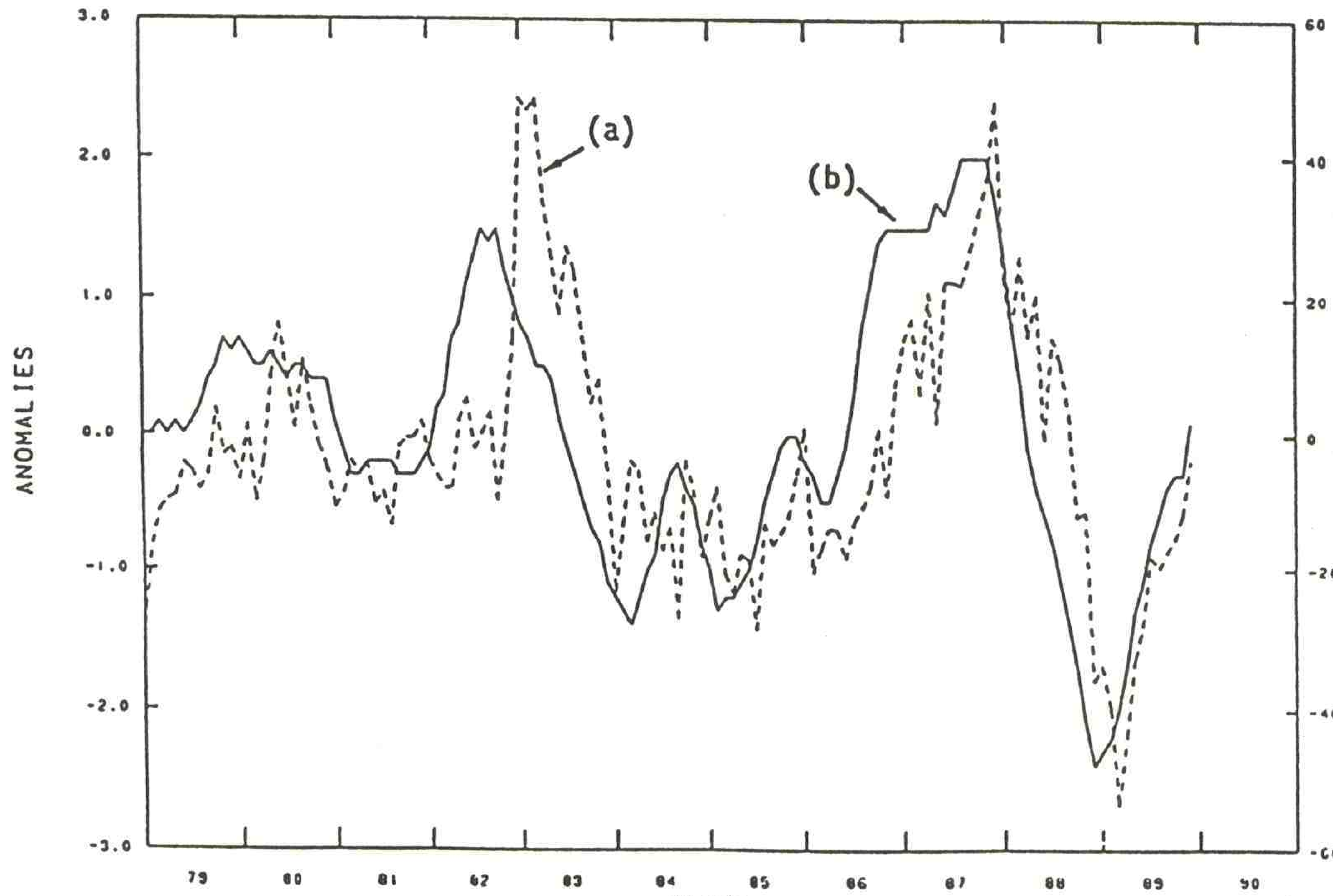


Figure 3 Time series of zonally averaged 200 mb height anomalies (a) and equatorial central Pacific (ship track 6) sea surface temperature anomalies (b). Height (SST) anomalies are computed with respect to the 1979-1988 (1951-1980) base period means. height (SST) anomalies are read on the right (left) axis and are in units of m (°C).

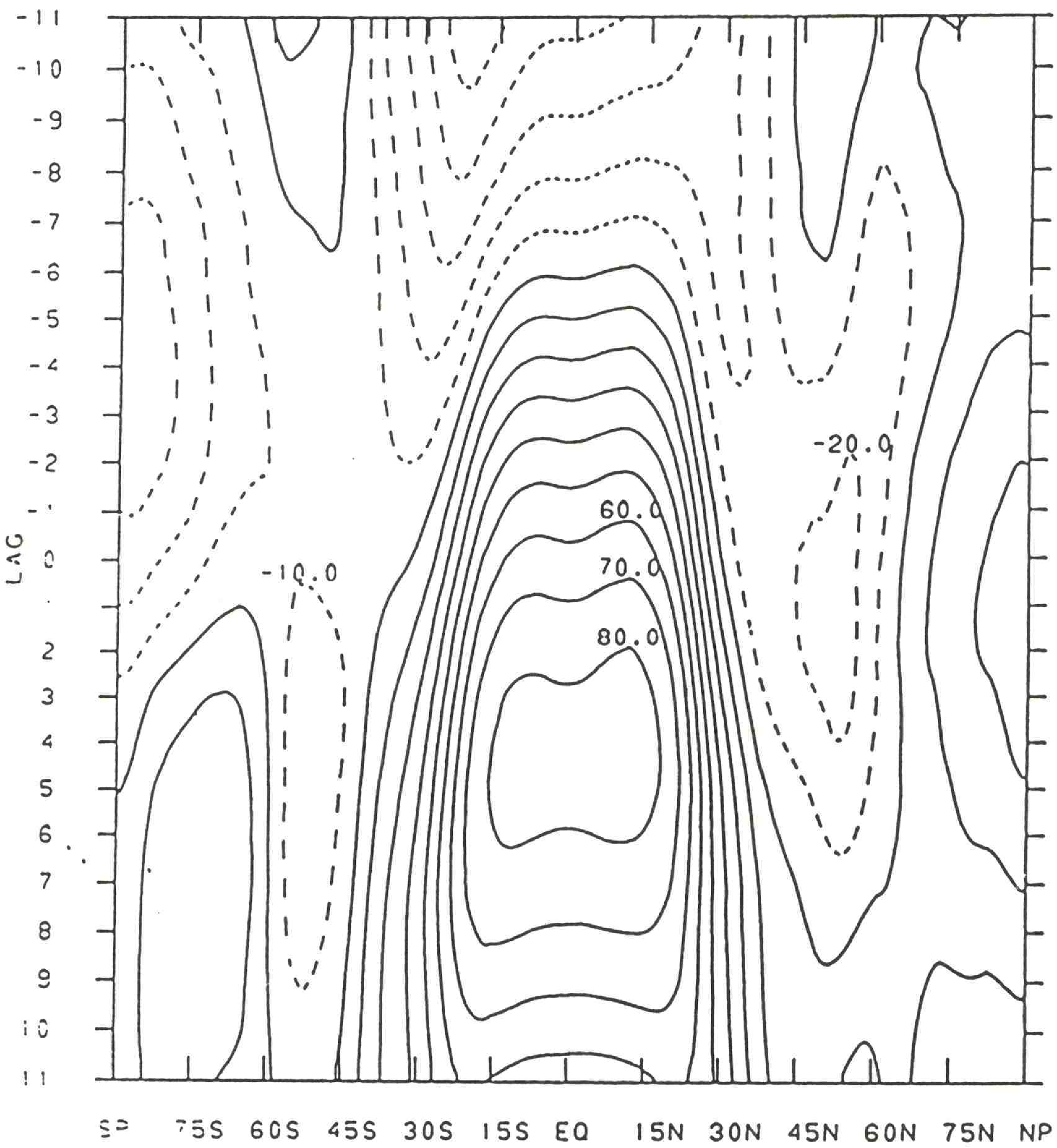


Figure 4 Correlation between anomalous sea surface temperature in the central equatorial Pacific and zonally averaged anomalous 200 mb height as a function of both lag (months) and latitude. Negative correlations are indicated by dashed contours. Positive (negative) lags indicate that 200 mb height anomalies have been shifted backward (forward) in time with respect to the SST anomalies. The maximum correlation along the equator at 4-5 months indicates that the SST anomalies lead the 200 mb height anomalies by 4-5 months.

A study was also completed on the relationship between sea level pressure variations and oceanic and atmospheric circulation changes. Results showed that basin-wide, in-phase sea level oscillations are negatively correlated with sea level pressure variations associated with atmospheric intraseasonal oscillations. These and other results were presented at an International Conference on Southern Hemisphere Meteorology.

1.1.3 Southern Oscillation Patterns (Halpert, Ropelewski)

A study was completed that examined temperature patterns associated with the extremes of the Southern Oscillation (SO). Twelve regions were found to have low SO-temperature relationships, while 11 areas were found to have high SO-temperature relationships (figure 5). Of these areas, 9 have relationships during both phases of the SO. In the tropics, temperature anomalies are of the same sign as the sea surface temperature anomaly in all regions except for one area in the west Pacific. The identified temperature responses are more consistent in tropical regions than in the extratropics. The above results were described in a paper that was submitted for publication (Journal of Climate).

1.1.4 ENSO Prediction (Ropelewski, Barnston)

Experiments are being conducted for El Niño/Southern Oscillation (ENSO) prediction using modifications of a statistical technique (developed by T. Barnett, et al, Scripps Institution of Oceanography). This technique is called the canonical correlation analysis (CCA) and it is being used to predict the sea surface temperature (SST) for an area in the central Pacific from 5^{o}N to 5^{o}S, 120^{o}W to 170^{o}W. CCA predictions have been made routinely since November 1989 and appear in CAC's Monthly Climate Diagnostics Bulletin.

An example of the CCA forecasts (1, 2 and 3-season lead) of SST and corresponding cross-validation skill scores is shown in figure 6. The skills (correlations that correspond to the observed and predicted SST are shown in the right hand column These correlations (skills) show a clear annual cycle, which is reflected by the error bars in the forecast time series on the left. The CCA forecasts appear to be most skillful in the Northern Hemisphere from late summer through early fall. Other numerical ocean-atmosphere models show the same general seasonality in their forecast skill. This suggests an inherent seasonality in the predictability of ENSO independent of a prediction technique.

1.2 Circulation Diagnostics

1.2.1 Large Scale Tropical Circulations (Mo)

A study was conducted on the atmospheric teleconnection dynamics during the 1987-89 ENSO cycle. Based on NMC analyses, the nature of the upper tropospheric divergent circulation was investigated and the results were compared to idealized concepts of regional Hadley cells and Walker circulations. It was found that NMC-analyzed divergent winds are realistic enough to provide useful information on seasonal conditions and year-to-year variations. For seasonal-mean features and ENSO-related departures, the largest vorticity sources are found in the subtropics and low mid-latitudes associated with the descending branches of the Hadley cell circulations (see figure 7). The 1987-89 ENSO

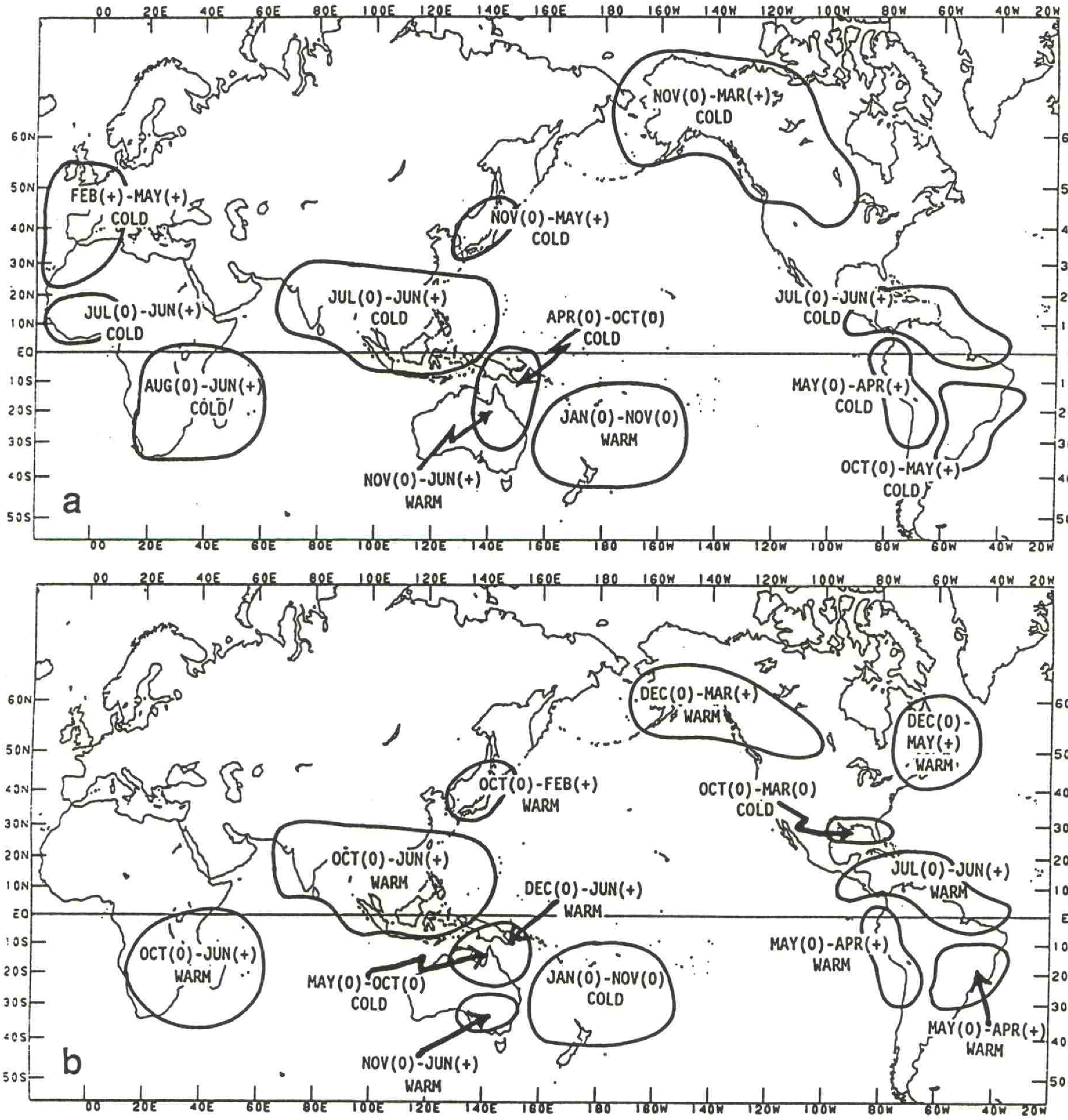


Figure 5 Schematic representation of the principal (a) high and (b) low SO-related temperature responses based on a detailed analysis for the core regions

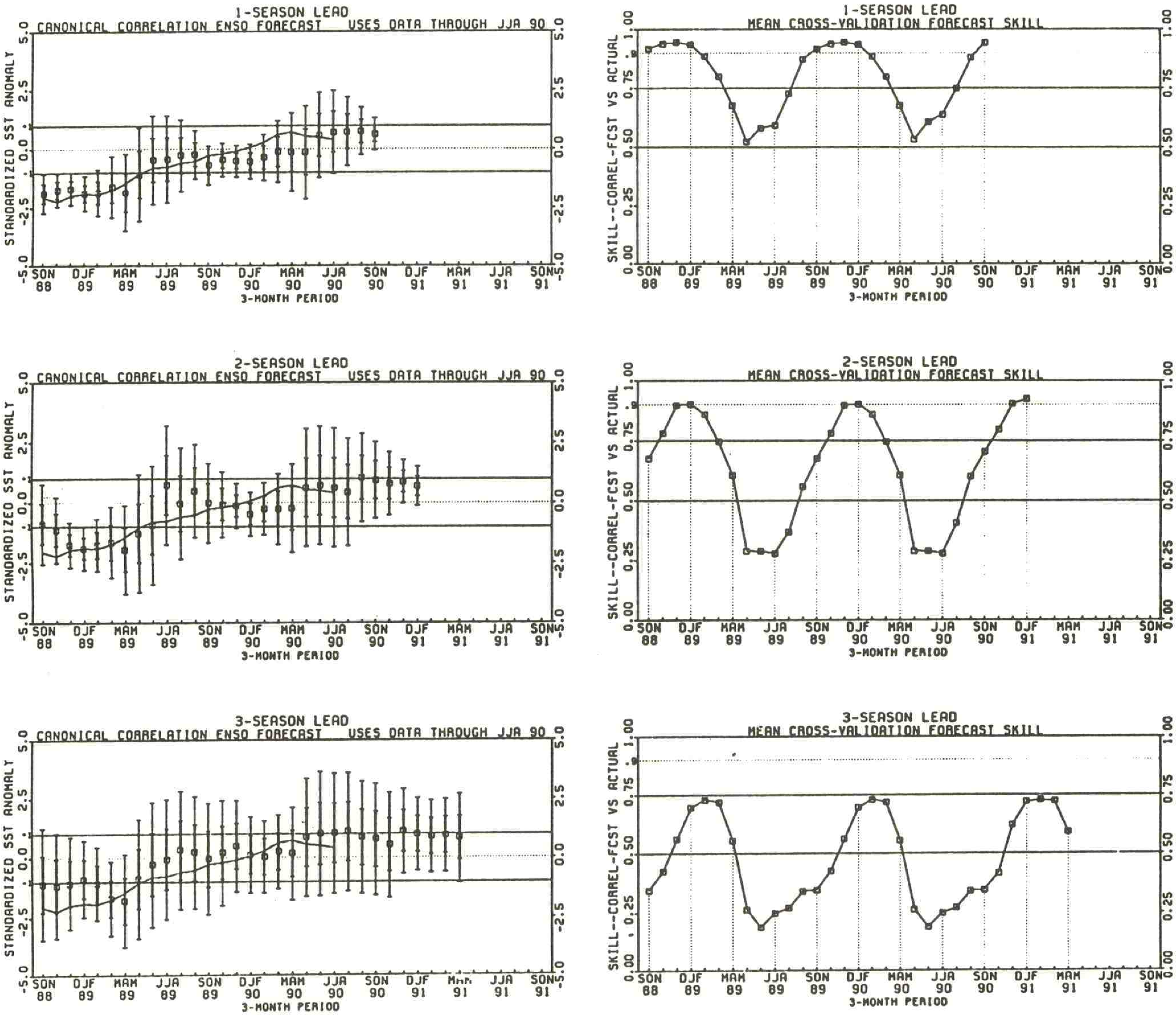


Figure 6 Canonical correlation analysis (CCA) predictions of sea surface temperature in the central Pacific and corresponding cross-validation skill scores. The three plots in the left hand column depict (from top to bottom) the 1-, 2-, and 3-season lead forecasts. The right hand column shows the skills (correlations) that correspond to the observed and predicted SST for 1-, 2-, and 3-season lead forecasts. The solid line in each left hand panel represents the observed SST standardized anomaly through the latest month. The small squares at the mid-points of the forecast bars represent the CCA predictions based on the global sea level pressure anomaly fields and on the SST patterns in the tropical Pacific over the previous four seasons. The one standard deviation error bars (thick lines) and two standard deviation (thin lines) error bars are based on past performance using cross-validation techniques.

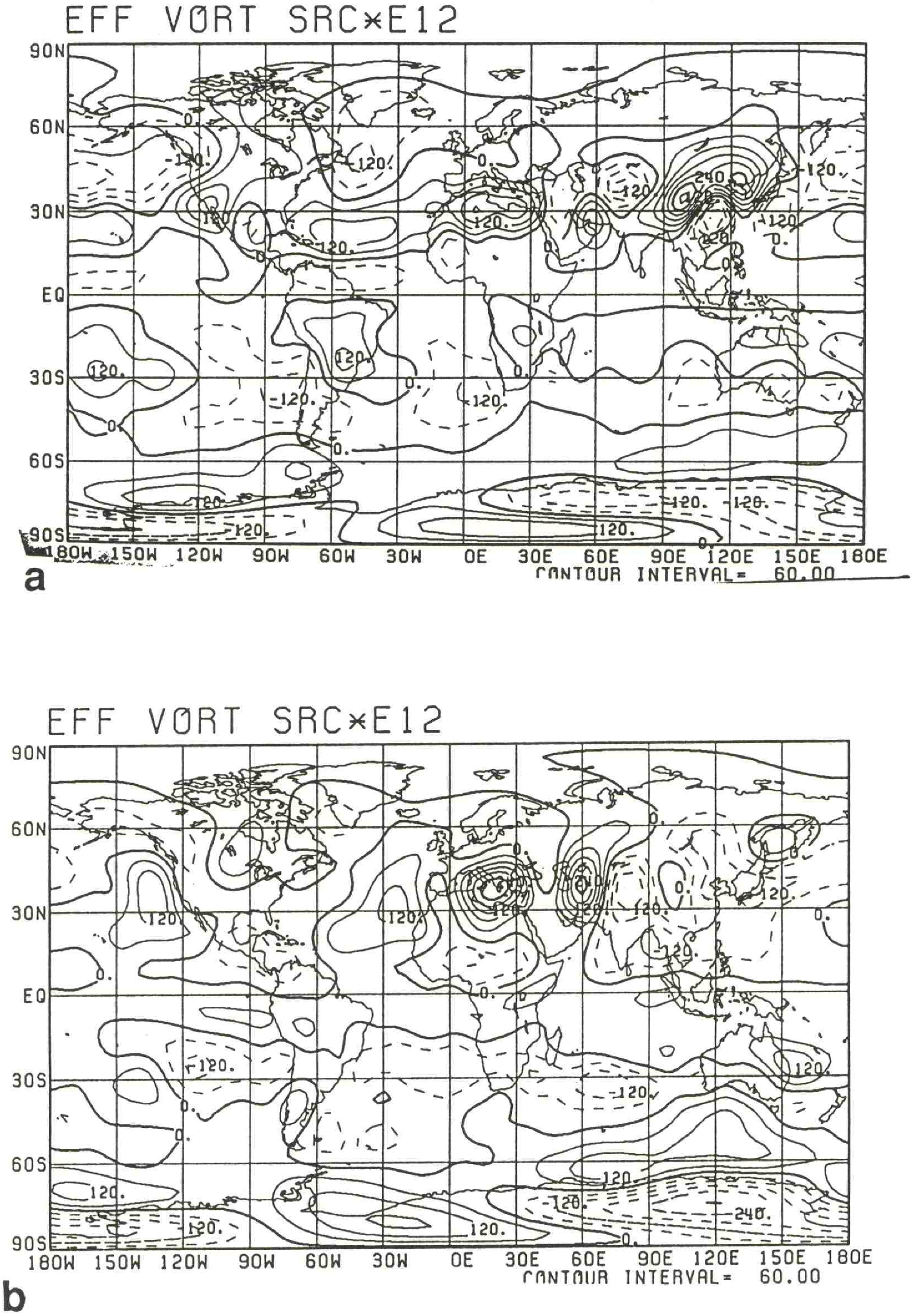


Figure 7 Vorticity sources for (a) the JFM season, and (b) the JJA season from NMC analysis from 1987-1989. Contour interval 6 x E-11/sec^2.

fluctuations appear to be typical of a moderate amplitude ENSO cycle. Also, the vorticity anomaly budget indicates that the main contribution to the vorticity balance in the extratropics comes from the anomaly-mean flow interaction.

1.2.2 Large-Scale Interaction (Ropelewski, Halpert, Wang)

A major effort is focused on the fundamental modes of temporal and spatial variability in the Southern Oscillation (SO). Biennial variabiity in the surface winds and sea surface temperature (SST) appears to be an important SO mode for both the western Pacific Ocean and the Indian Ocean. Also, significant coherence between the monthly mean zonal wind component at 90^{O}E and the monthly mean SST across the Pacific basin (see figure 8), suggests that conceptual and numerical models of the SO must include the Indian Ocean. While biennial variablity apparently is one of the important modes in the evolution of the SO, the annual cycle appears to play a fundamental role in the phase of this biennial variability.

1.2.3 Climate Model Diagnostics (Mo)

A diagnostics study was performed on modeled output based on the Climate Data Assimilation System (CDAS). Thirty-day assimilations were run for July 1989 for 3 different horizontal resolutions using the present model. The identical data were inserted into the assimilation processes, with the only difference being in the horizontal resolution. (The rotational part of the flow is not sensitive to the resolution.) The results show major differences in the divergent winds. In the tropics, the low-resolution model consistently underestimates divergence and associated convergence especially over central America, the eastern Pacific, and western Africa. The low-resolution model also produces weaker Hadley cells and underestimates rainfall.

In another diagnostics study, an evaluation was made on the moisture budget derived from NMC analyses. Moisture budget values were computed using high-resolution data (4 times daily) for 12 vertical levels from the surface to 300 mb. The calculations are sensitive to the horizontal resolution, vertical resolution and time intervals. Figure 9 shows the divergence of moisture fluxes that were calculated from high and low resolution runs over the U.S. for July 1989. It can be noted that the pressure level output from the low-resolution run cannot capture small scale features. In addition, because the major moisture transport occurs at the 950 mb level and the diurnal cycle is very strong for certain land masses, it is evident that a high-resolution model is needed to produce this computation.

An additional study was conducted to test the impact of sea surface temperature anomalies (SSTA's) on 30-day forecasts for the Northern Hemisphere summer. Two sets of experiments were performed: the first set consisted of 30-day forecasts with SSTA fixed at the initial date during the integration; the second set used the same initial conditions as the first, but was run with climatological SST (CSST). Preliminary results show that SSTA's have a clear positive impact on the tropical forecasts and surface variables, such as surface stresses and latent heating. The impact on extratropical forecasts tends to be small. Figure 10 shows anomaly correlations for daily ensemble means of 500 mb height anomalies for the CSST and SSTA experiments for both the Southern and Northern Hemisphere. During the first 10 days, there is no significant impact

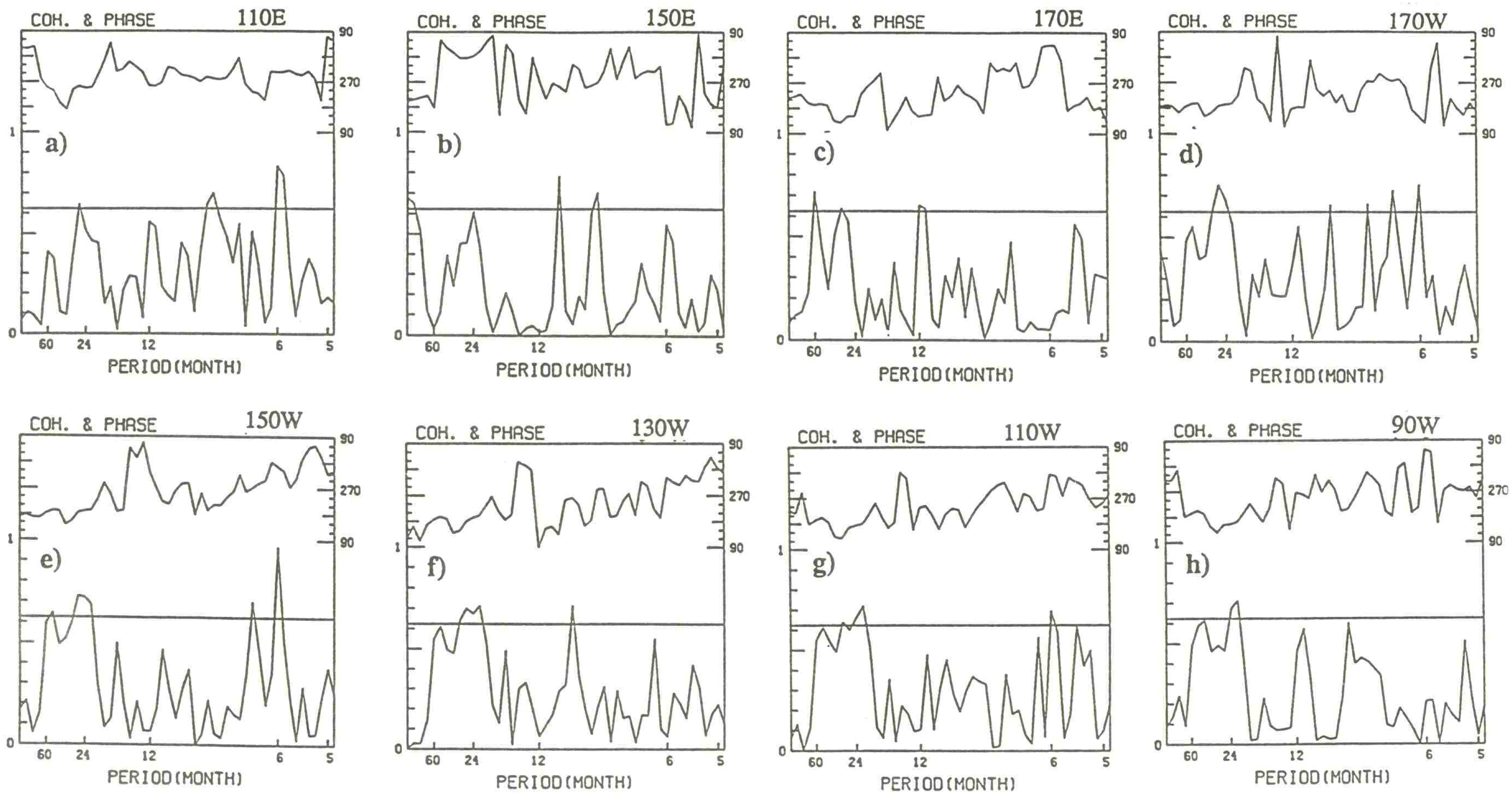


Figure 8 Coherence between the monthly mean zonal wind component at 90°E and monthly mean sea surface temperature anomaly at a) 110°E, b) 150°E, c) 170°E, d) 170°W, e) 150°W, f) 130°W, g) 110°W, and h) 90°W. No analysis was performed for the mixed ocean/island regime centered at 130°E. The significant biennial coherence between the winds in the Indian Ocean and the sea surface temperature across the equatorial Pacific Ocean suggests that the Indian Ocean must be included in models of the Southern Oscillation.

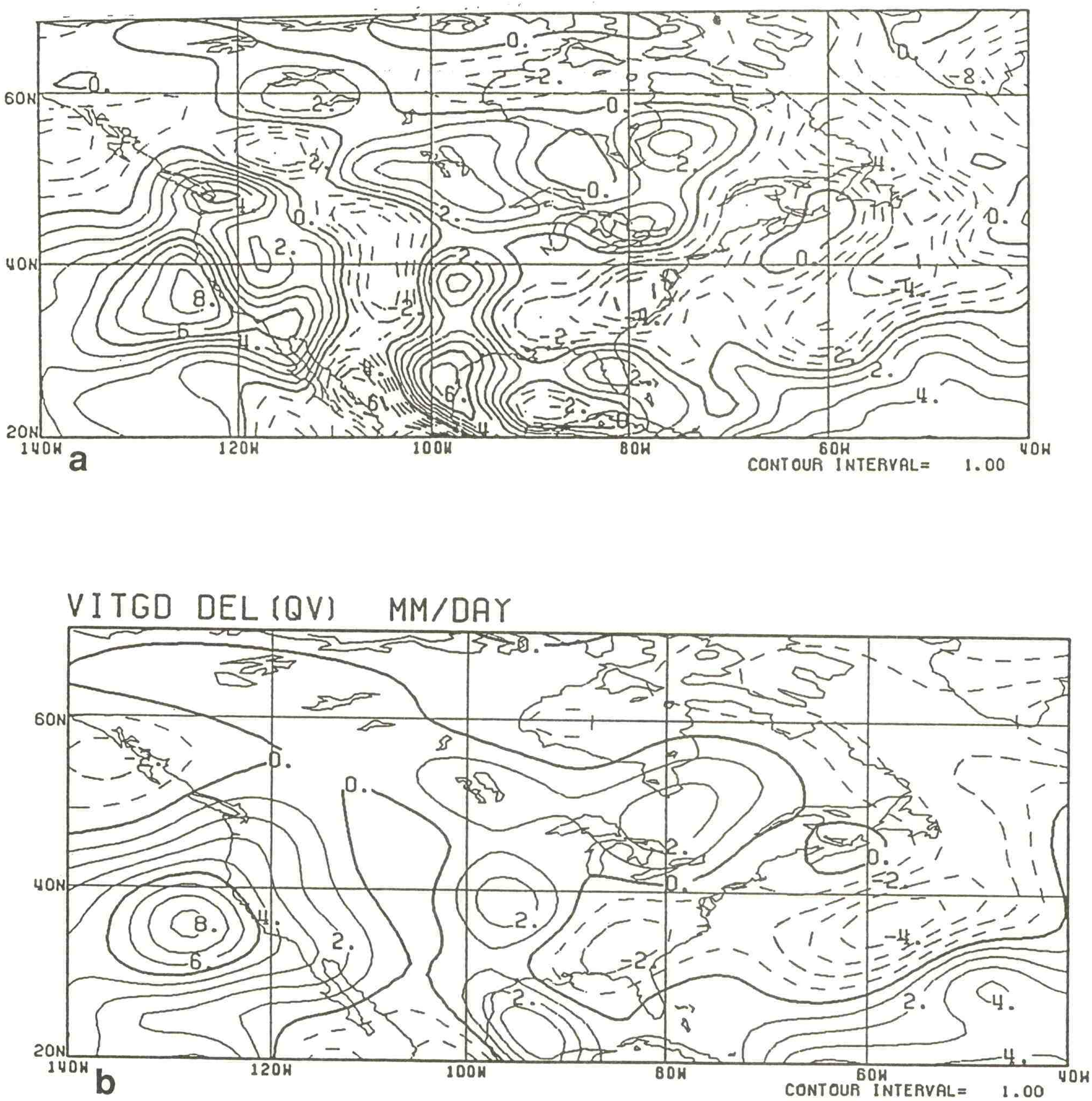


Figure 9 Vertical integrated divergence of moisture flux [del (QV)] over the United States for July 1989 from NMC analyses, (a) calculated using the T80 resolution and (b) using the R30 resolution. Contour interval 300 g/(cm*sec).

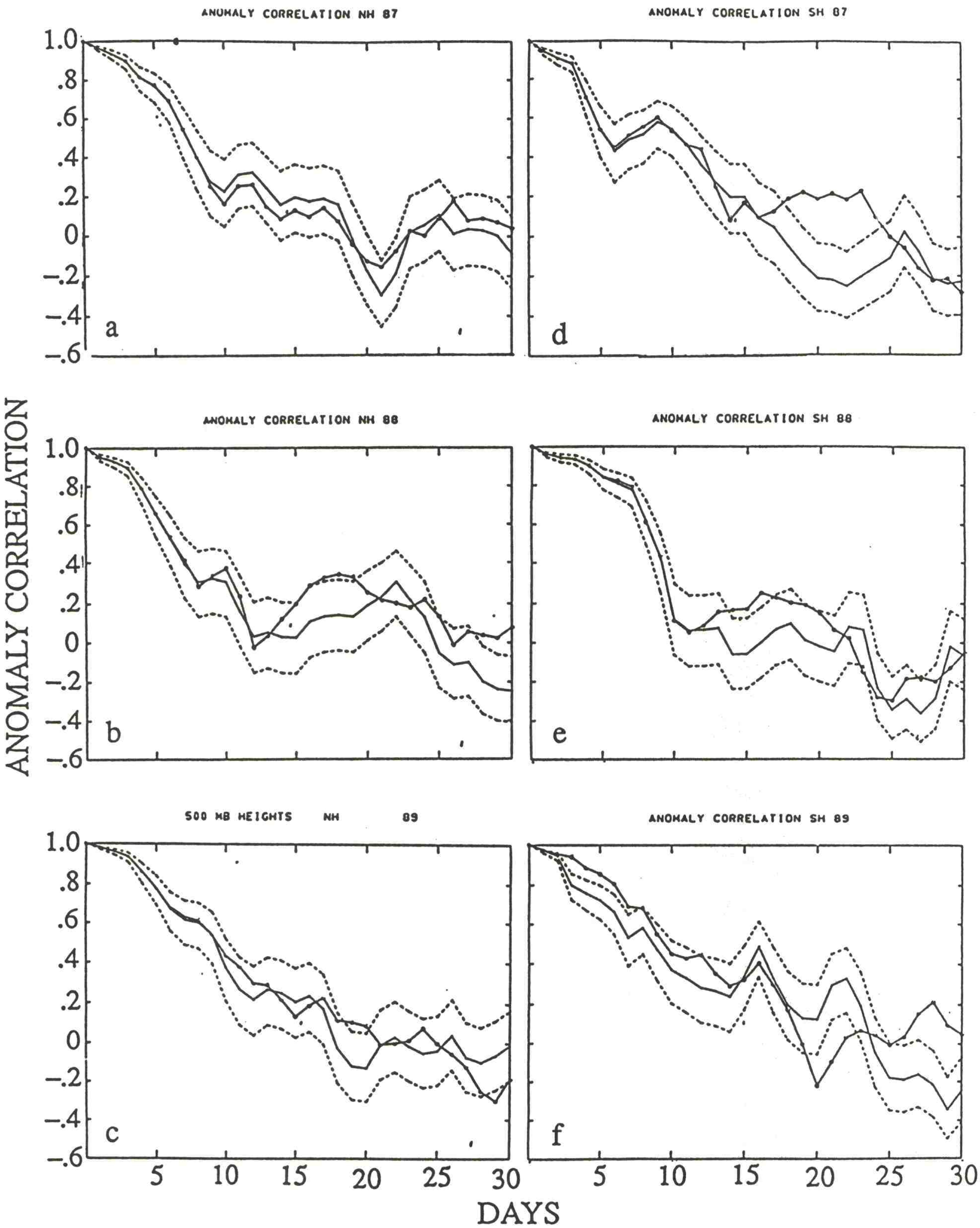


Figure 10 Anomaly correlation for daily ensemble forecasts for (a) 1987 NH, (b) 1988 NH, (c) 1989 NH, (d) 1987 SH, (e) 1988 SH and (f) 1989 SH 500 mb heights. Dark solid line is for CSST experiments, dark solid line and circle is for SSTA experiments and dashed lines are for statistical confidence levels for the CSST experiments.

in skill for experiments with and without SSTA. After that time, the SSTA start to improve the forecasts; however, the anomaly correlations drop to the point of having little or no skill. For mid-latitudes, large positive impacts occur only when the atmospheric circulations are driven by the ocean anomalies.

1.2.4.1 Tropical Convection/Atmospheric Circulation (Kousky)

A collaborative study (C. Studzinski et al; INPE, Brazil) was conducted on rainfall variations in Northeast Brazil and related global atmospheric circulation changes during November 1989-March 1990. Results indicate that a large part of the temporal variability in rainfall can be related to phases of the 30-60 day (intraseasonal) oscillations. These oscillations were extremely active during the above period and affected not only northern South America, but also the Indian Ocean region, Indonesia, the Philippines, and northern Australia.

1.2.4.2 Tropical Convection/Atmospheric Circulation (Chelliah)

A joint study (with P. Arkin, OAR) was completed that employed rotated principal component analysis (RPCA) of monthly outgoing longwave radiation (OLR) anomalies over the global tropics. The broad aspects of large scale interannual and long-term variability, as derived from mean OLR data from NOAA's polar orbiting satellites, were examined from June 1974-March 1989. The results described both the physical and nonphysical variability in the data set. The leading physical modes included a "canonical El Niño Southern Oscillation (ENSO) mode" and the dominant 1982-83 ENSO mode. The canonical ENSO mode describes all the major warm and cold El Niño events during 1974-1989. The nonphysical modes documented the spatial and temporal variability in the OLR data set associated with different local observation times and different algorithms.

In a follow-up study, tropical-extratropical teleconnections were examined as a function of temporal scale. Joint principal component analysis (JPCA) and singular value decomposition were used and the results for the leading second, third and forth rotated modes are shown in figures 11, 12 and 13. The second eigenmode (figure 11), not surprisingly, is dominated by the 1982-83 warm ENSO event. This is evident by the large negative OLR anomalies in the central and eastern Pacific, and southern Indian Ocean, as well as positive OLR anomalies over Indonesia and northeast Brazil. The time series for the third eigenmode (figure 12) illustrates the temporal variability associated with the spatial loading patterns of OLR and upper and lower vorticity changes representing a canonical ENSO mode. In both figures, the upper and lower level vorticity changes are also quite consistent with the OLR changes in the tropics.

The fourth mode in this analysis, (figure 13), shows somewhat surprising patterns. Results show the spatial loading for OLR consists of dipoles in the tropical central Pacific and Atlantic, asymmetric about the equator. The time scale associated with the time series of this mode is longer than the intraseasonal, but shorter than the ENSO time scale. The tropical and extratropical vorticity patterns fit very well with the schematic of energy propagation from low to higher latitudes (proposed theoretically by other researchers). The evidence for the Northern Hemisphere winter season being the preferred season for this kind of energy propagation is clearly present in the time series. Moreover, the vorticity loadings over North America are much larger than those associated with the 1982-83 mode or the canonical ENSO mode.

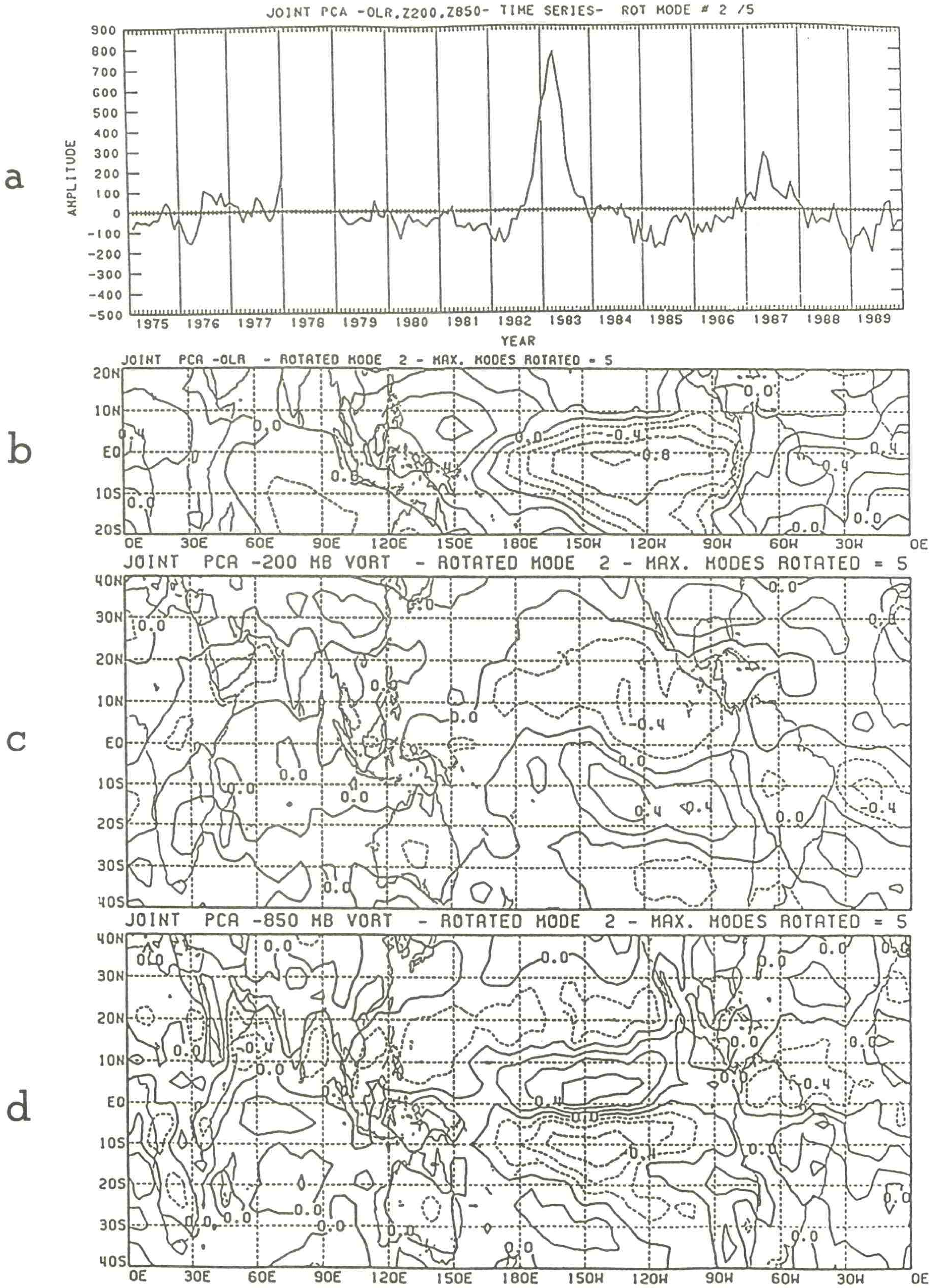


Figure 11 Panels (a) through (d) show respectively the time series, the spatial loading patterns for OLR over 20^{o}N-20^{o}S, 200 mb vorticity over 40^{o}N-40^{o}S, and 850 mb vorticity over 40^{o}N-40^{o}S for the second rotated principal component from JPCA.

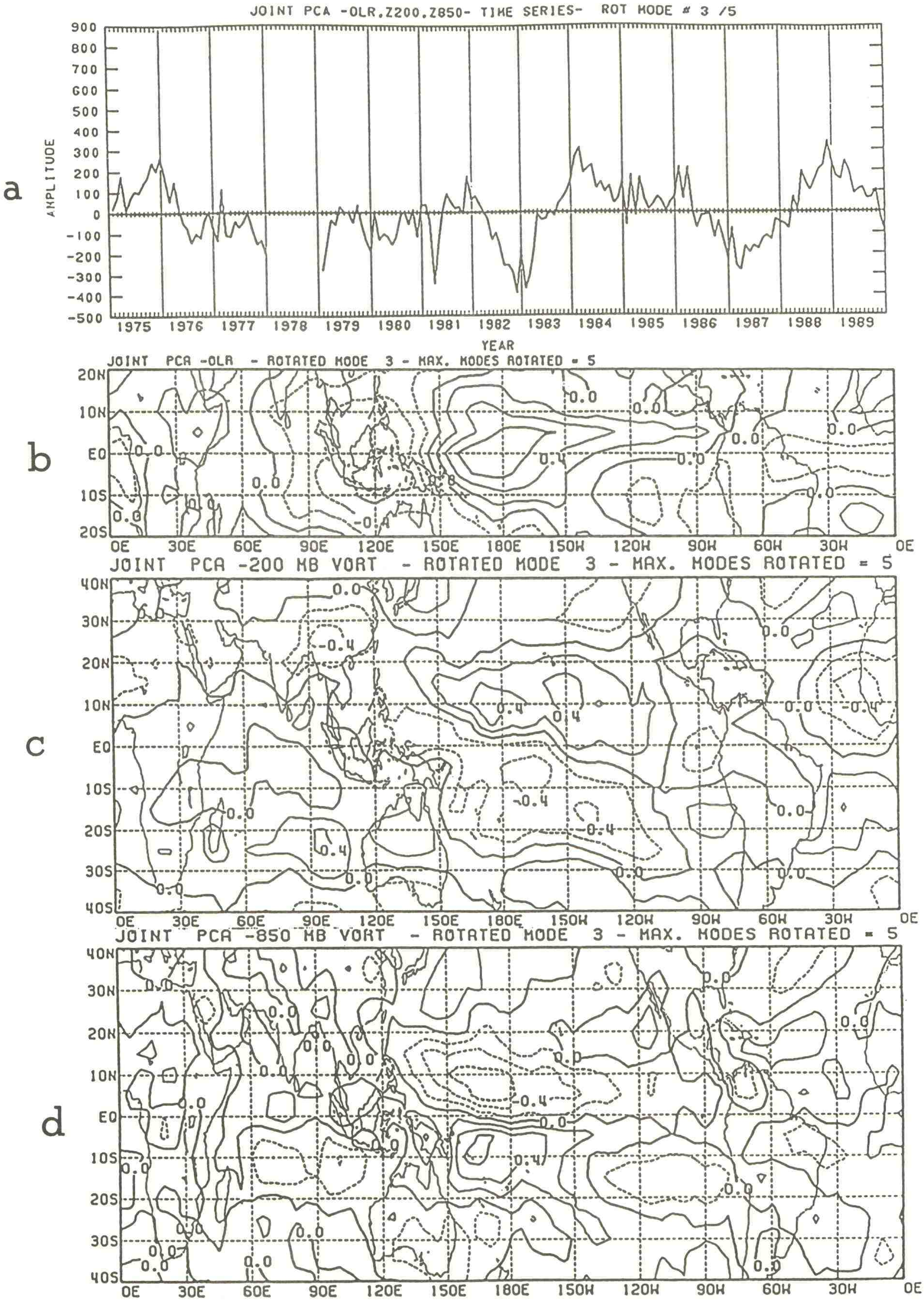


Figure 12 As in figure 11, except for the third rotated principal component.

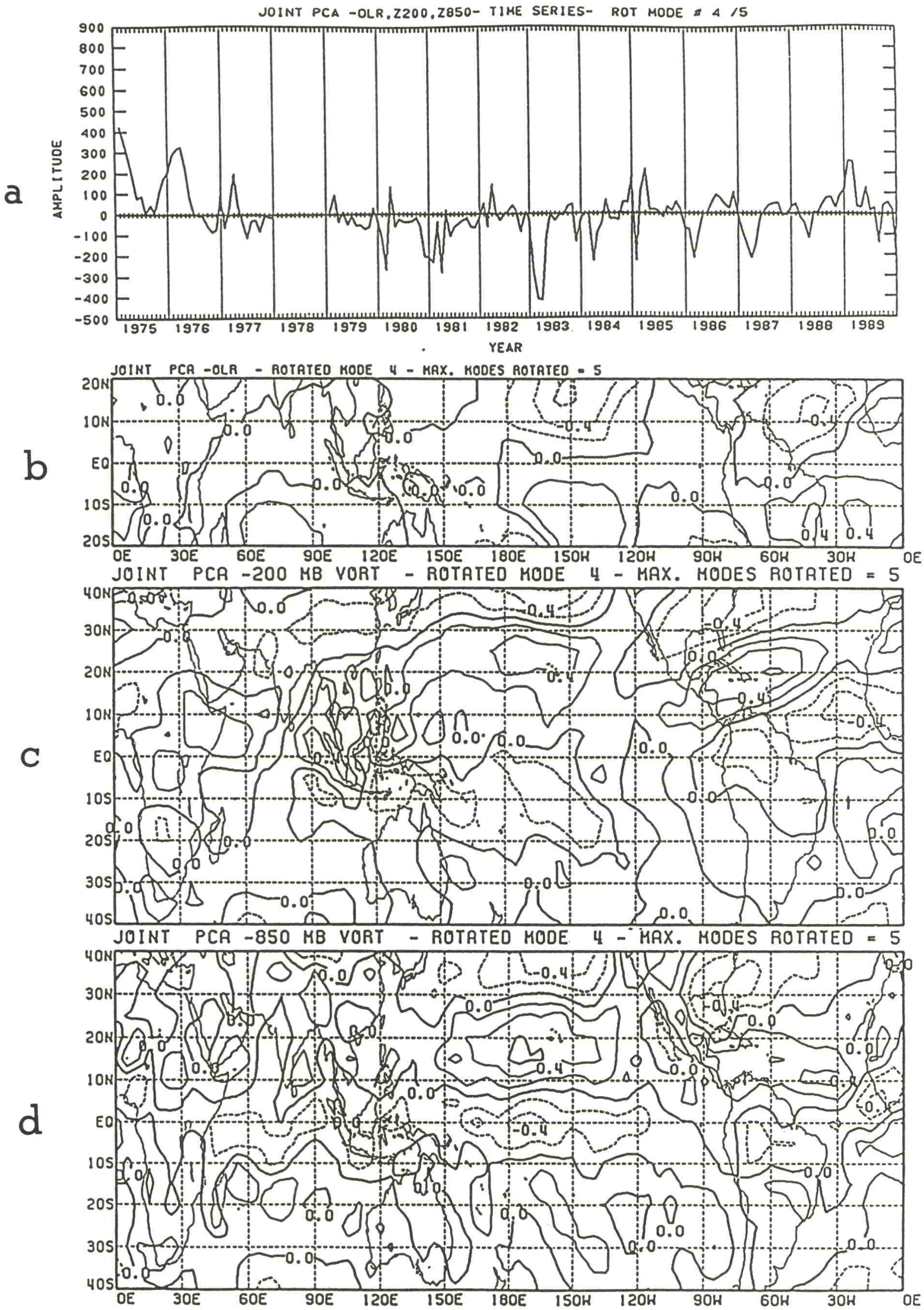


Figure 13 As in figure 11, except for the fourth rotated principal component.

2. CLIMATE MONITORING

2.1 Surface Climate

2.1.1 Surface Climate Anomalies (Halpert)

The Climate Anomalies Monitoring System (CAMS) data base has been converted to the Virtual Storage Access Method, which enables CAMS to be run through the 1990's. Historical precipitation data for China and Africa have been added to the CAMS data files. These data improve the monitoring of the current climate and provide a larger data base for climate diagnostic studies.

2.1.2 Climate Calendar (Ropelewski, Garrett, Halpert)

CAC input was part of a joint Climate and Global Change/Tier II proposal with NESDIS/National Climatic Data Center and the NOAA/Environmental Research Laboratories. This proposal, entitled "Development of a Global Climate Perspective System," seeks hardware and software support to improve data bases, graphics and other Climate Calendar related products. As a result, a Sun workstation was obtained and software is being developed to support Climate Calendar data bases and analyses.

2.1.3 Normalized Difference Vegetation Index (Halpert, Ropelewski)

A five-year climatology (April 1985 - March 1990) of Normalized Difference Vegetation Index (NDVI) values has been produced jointly (with NESDIS). The temporal consistency of the index has been examined through the use of time series over different vegetation surfaces. Large spikes were found which are believed to be caused by scan angle differences. Consequently, a scheme using a three-week median filter was adopted to temporally smooth the data. Global difference fields have been produced to examine vegetation changes during a low phase ENSO year (1987) and a high phase ENSO year (1988). Results showed wetter (greener) conditions prevailing during 1988 in India and northeast South America with drier (browner) conditions in southeast South America.

Based on median-filtered weekly data, NDVI anomaly maps have also been generated for various weeks and years. It was discovered that anomaly maps for 1989 and 1990 have a negative bias, with large areas of the globe having negative NDVI anomalies. This bias is apparently associated with the switch from the NOAA 9 to NOAA 11 satellite, which resulted in the local equator crossing time changing from 4:30 p.m. to 1:00 p.m. This time change appears to affect NDVI values over desert regions (figure 14). The values become greater as the crossing time gets earlier (higher solar zenith angle). A study is currently underway to identify whether this change affects the NDVI over vegetated surfaces as well.

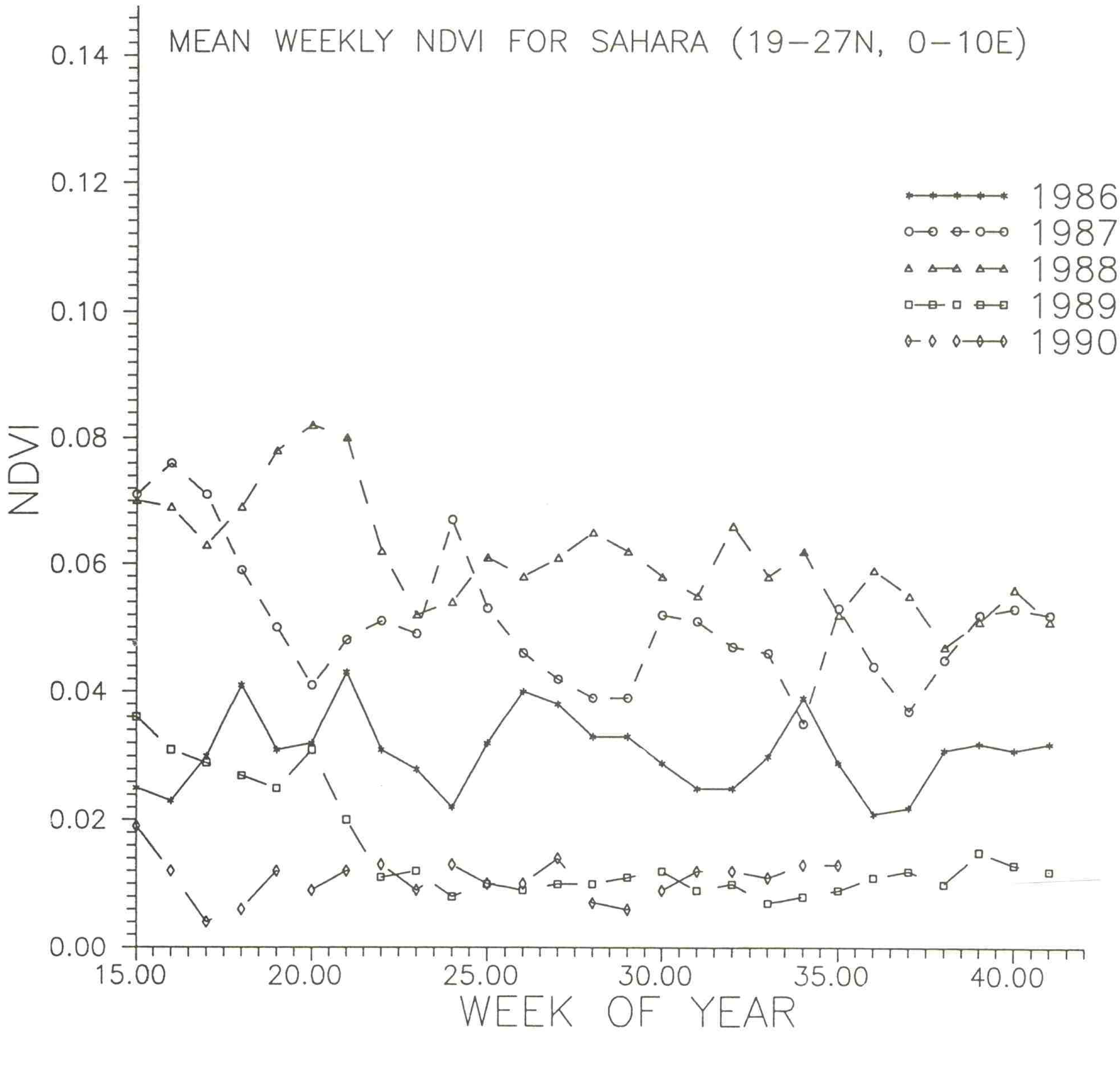


Figure 14 Weekly time series of NDVI for a region in the Sahara desert. The data were smoothed using a 3 week median filter.

2.1.4 Snow/Ice Monitoring (Ropelewski, Garrett)

A preliminary comparison study revealed that the estimates of Northern Hemisphere surface temperature anomalies were inversely related to snow cover area anomalies. The relationship appears to be strongest for the Spring season over the Eurasian sector. As shown in figure 15, the extreme March 1990 surface temperature anomaly is clearly related to the record (1973-1990) snow cover deficit over Eurasia.

A paper on the evaluation of global sea-ice trends was revised for inclusion in an Intergovernmental Panel on Climate Change (IPCC) Report. One component of this Report discussed a time series of Antarctic sea-ice area, which shows decreasing values during the 1970s followed by a rapid recovery in the early 1980s.

2.1.5 Climate Trends (Ropelewski, Halpert)

The influence of the Southern Oscillation (SO) on global and hemispheric temperature estimates were written for an Intergovernmental Panel on Climate Change Report. Analyses suggest that it is more appropriate to monitor global temperatures with seasonal data to separate SO-related temperatures from other sources of variability. The mean interannual temperature anomaly differences, associated with SO extremes, are estimated to be 0.2^{o}C for the October-March period in the Northern Hemisphere. In areas directly linked to the SO, the mean interannual difference may be more than 0.5^{o}C.

Several products were generated for CAC's climate assessment for 1989. These include: hemispheric and global surface temperature time series, 500 mb temperature anomalies, global sea surface temperature anomalies, U.S. precipitation indices, as well as snow cover and sea-ice areal values. These products will also be generated for a climate assessment for 1990. Preliminary analysis of hemispheric and global surface temperatures suggest that 1990 will include the largest single positive monthly anomaly (March 1990).

2.1.6 Sea Surface Temperature Data Center (Reynolds, Marsico)

The present TOGA SST product is designed to use in situ (ship and buoy), satellite, and ice data. It has been discovered that the ice data have a major impact on the analyses north of 60^{o}N and south of 50^{o}S. For this reason, the ice data were added to all monthly analyses beginning with January 1989. Also, because ice data are important in monitoring global SST trends, all monthly analyses were recomputed using ice data for the 1982-1988 period. These reanalyzed SST fields have been sent to other data centers and individual investigators.

An investigation was initiated (as requested by the International TOGA Project Office) to determine what effect the delayed mode in situ observations have on the blended TOGA SST product. A pilot study has been completed for the months of January, April, July and October 1985. The results show that the delayed mode observations significantly increased the total number of in situ observations. However, the blended field only showed significant effects (absolute changes greater that 0.5^{o}C) in small isolated regions. Thus, the changes in the in situ data were minimized by the impact of the satellite data.

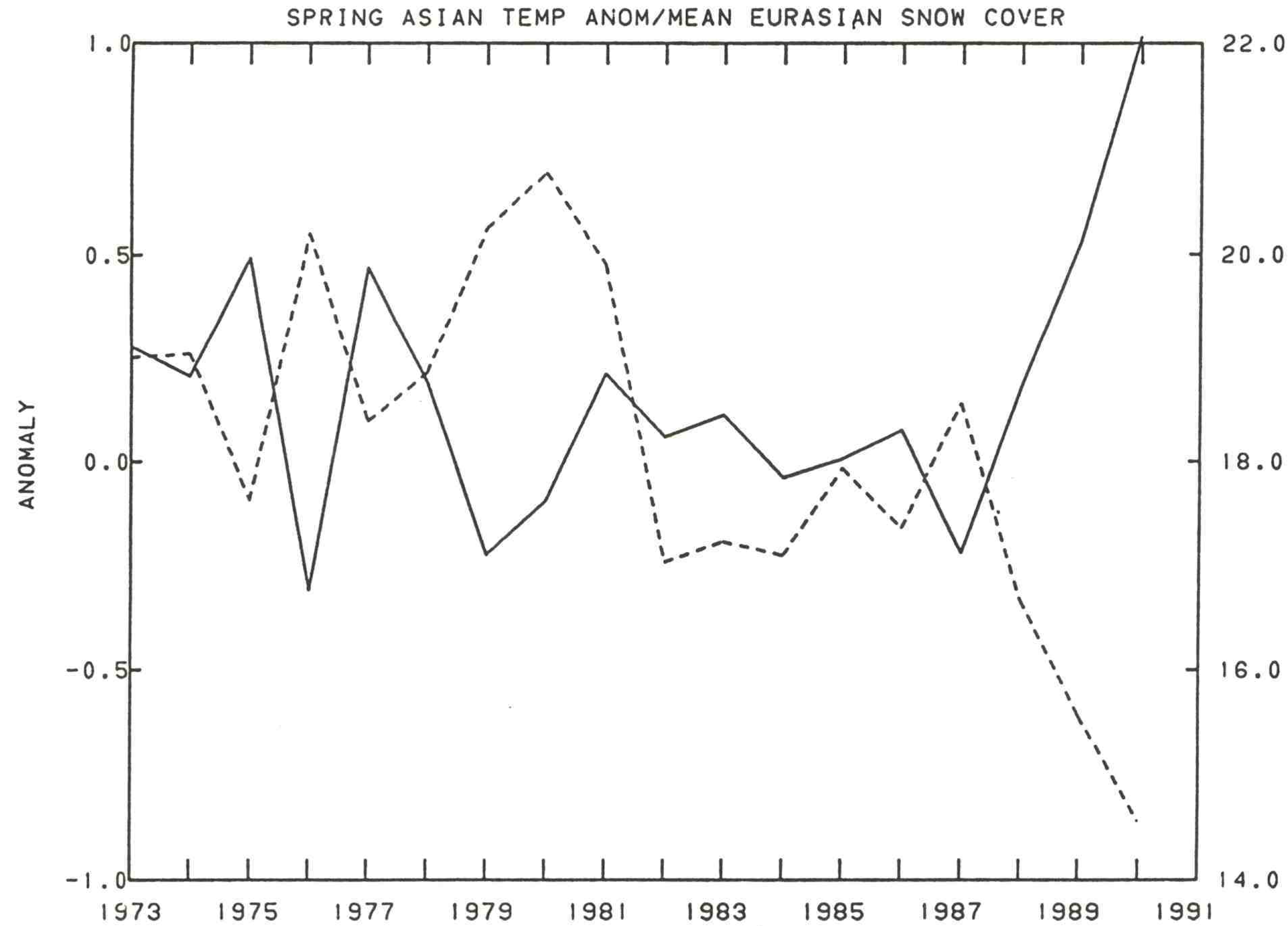


Figure 15 Time series of the Northern Hemisphere Spring snow cover area derived from analysis of visible satellite imagery (dashed) and the time series of Northern Hemisphere temperature anomaly (solid) from the GTS.

A higher resolution (1^{o} grid) SST analysis is now produced daily and weekly (with L. Breaker, NMC/Ocean Products Center), using the optimum interpolation (OI) method. The OI-method uses the same data as the TOGA product; however, because of the higher spatial and temporal resolution requirements, the quality control procedures have been improved. An example of the SST analysis, based on OI method, is shown in figure 16 and can be compared with the TOGA SST product (shown in figure 17). The higher resolution of the OI-derived SST is apparent, as it displays more realistic cold tongues in the tropics, the equatorial eastern Pacific, and Atlantic Oceans. At higher latitudes, the OI analyses show tighter gradients particularly in the Gulf Stream and the Kuroshio. The analyses also agree with satellite data and SST patterns obtained from ocean model simulations. Consequently, the analyses are being used to support CAC's ocean modeling effort and, after further testing, will be used to specify the lower boundary conditions for the NMC/MRF model.

2.2 Clouds and Precipitation

2.2.1 Global Precipitation Climatology Project (GPCP)

2.2.1.1 Geostationary Satellite Precipitation Data Center (Janowiak)

The Geostationary Satellite Precipitation Data Center is now operational. This Data Center provides tropical rainfall estimates from geostationary satellite infrared data for the Global Precipitation Climatology Project (GPCP). Rainfall estimates for the global tropics have been processed for the 1986-1989 period and were forwarded to the GPCP Center of the German Weather Service in Offenbach, FRG. Subsequent data processing and shipment have also proceeded according to the schedule in the Project Implementation Plan.

As part of the GPCP, work was initiated on the the Algorithm Intercomparison Project. The purpose of this project is to evaluate various rainfall estimation algorithms that are applied to the same data that were measured near Japan during June and August 1989. Visible and infrared data from the GMS geostationary satellite and microwave imagery from the Special Sensor Microwave/ Imager (SSM/I) aboard the DMSP polar orbiting satellite were provided to all project participants. When the rainfall estimates from each method are received by the Precipitation Data Center, an evaluation of these estimates will be made by comparing them with observed rainfall from stations in the high-density radar/raingage Japanese Amedas network.

2.2.2 Tropical Rainfall (Janowiak)

In this study, satellite-derived rainfall estimates were compared with simulations of precipitation, low-level moisture, and vertical motion from the NMC/Medium Range Forecast (MRF) model for the 1986-88 period. Figures 18 and 19 show time-longitude graphs of 850 mb specific humidity and 500-mb vertical velocity from the MRF model, while figure 20 shows the satellite-derived rainfall estimates. A comparison shows that there is reasonable agreement among the modeled fields and satellite-derived rainfall estimates. In the region bounded by the dateline and 90^{o}W, the MRF moisture and vertical motion fields contain features that propagate eastward in concert with the rainfall estimates during early 1986 and again in mid-1988. Similar agreement is noted between the estimated rainfall and low level moisture during early 1988.

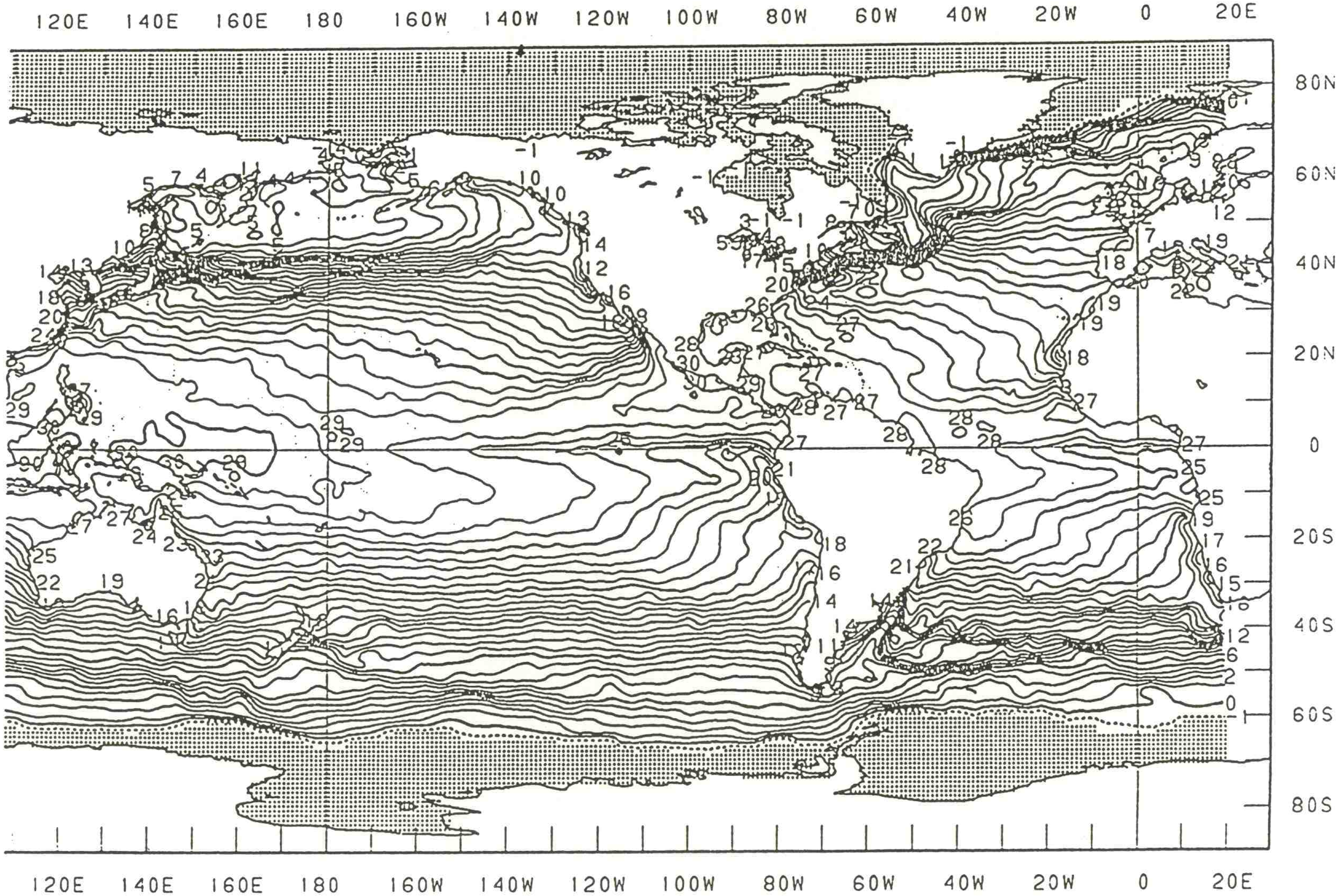


Figure 16 Sea surface temperatures from the OI analysis for the period June 17-23, 1990. The contour interval is $1^{0}C$. Positive contours are solid lines; negative contours are dashed; the zero contour is a heavy line. Regions covered by sea ice are stippled.

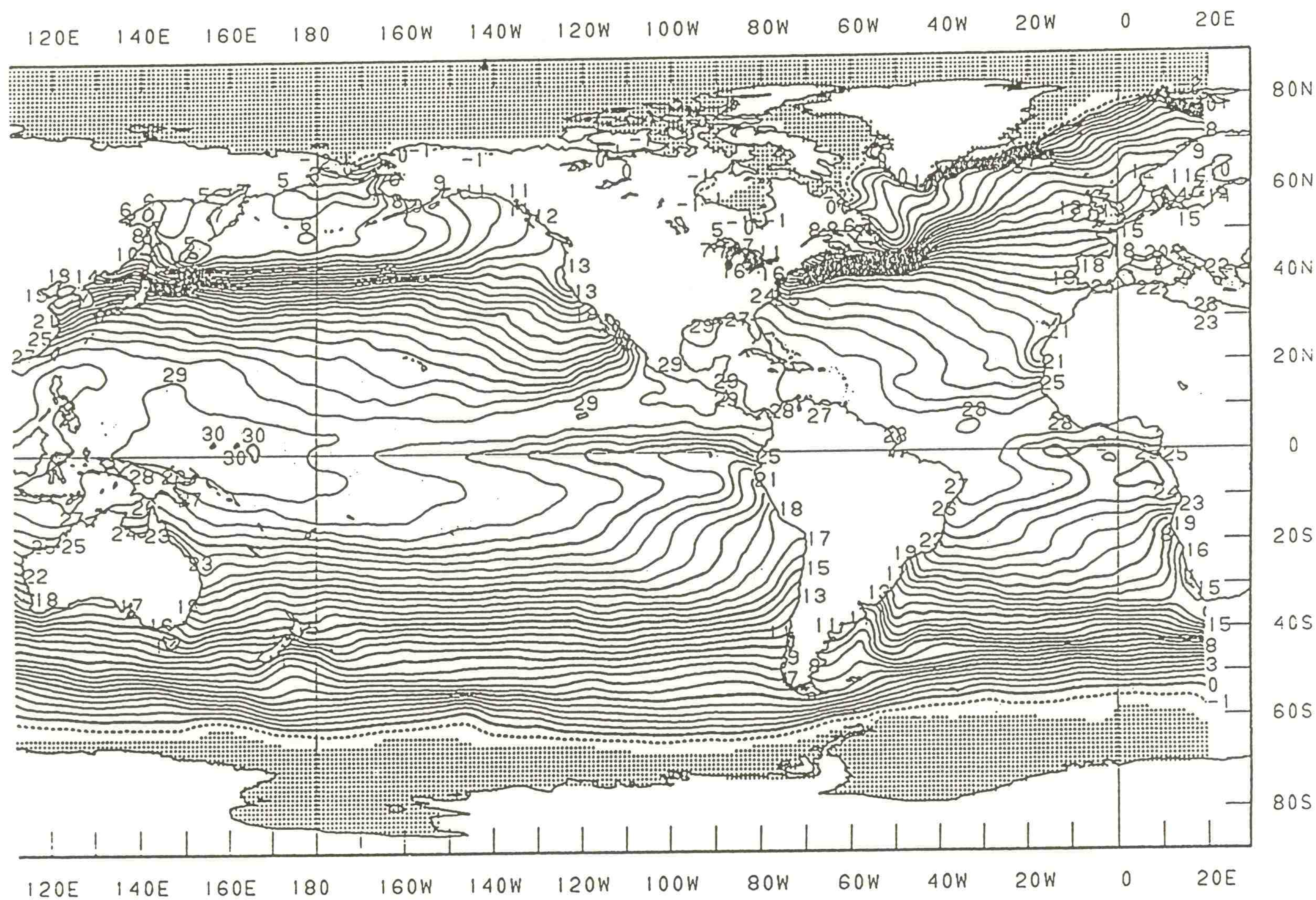


Figure 17 Sea surface temperatures from the TOGA analysis for the period June 13-27, 1990. The contour interval is 1°C. Positive contours are solid lines; negative contours are dashed. The zero contour is a heavy line. Regions covered by sea ice are stippled.

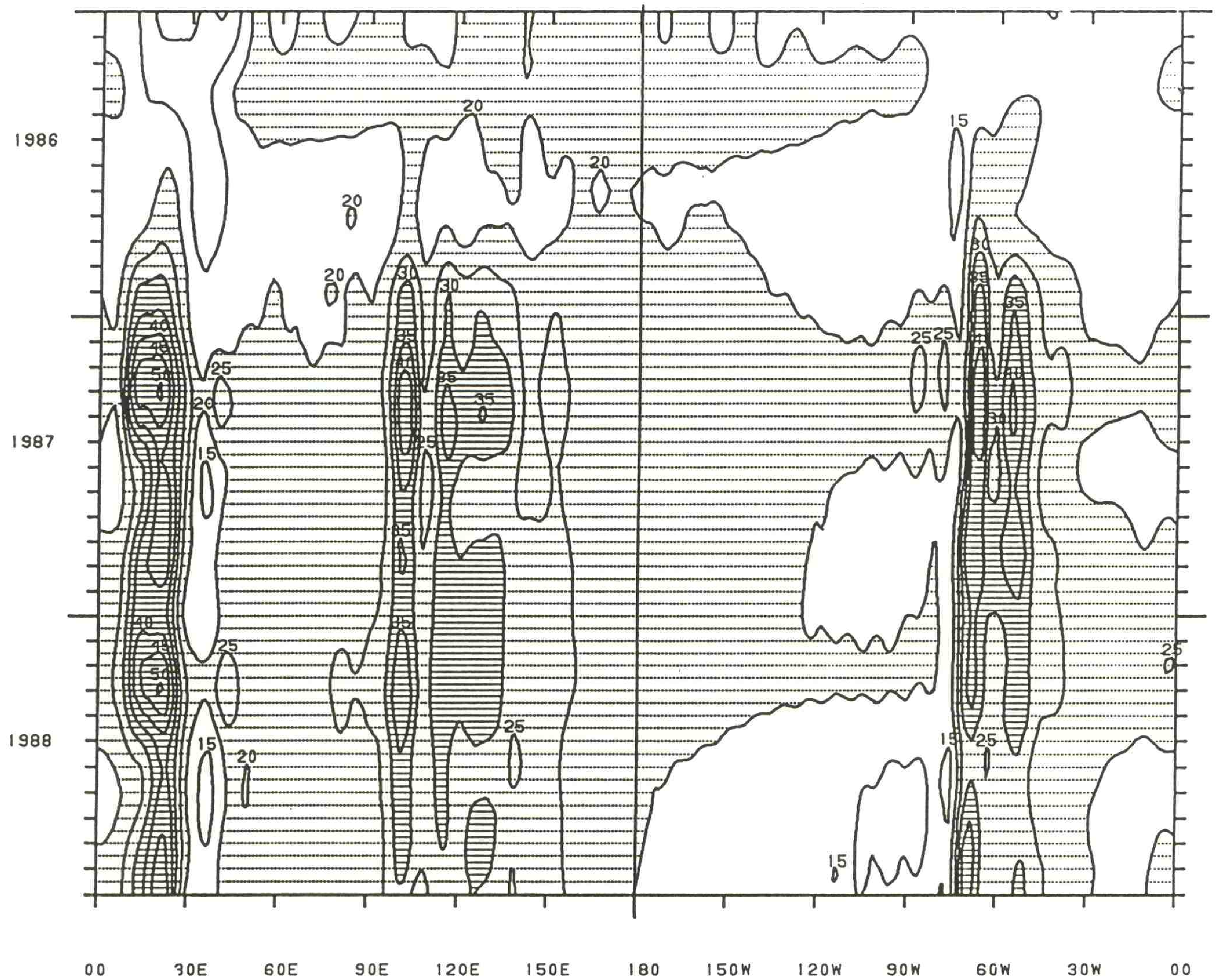


Figure 18 Time-longitude diagram ($7.5^{o}N$ - $7.5^{o}S$) of specific humidity (g/kg) at the 850 mb level from the NMC MRF model during 1986-88.

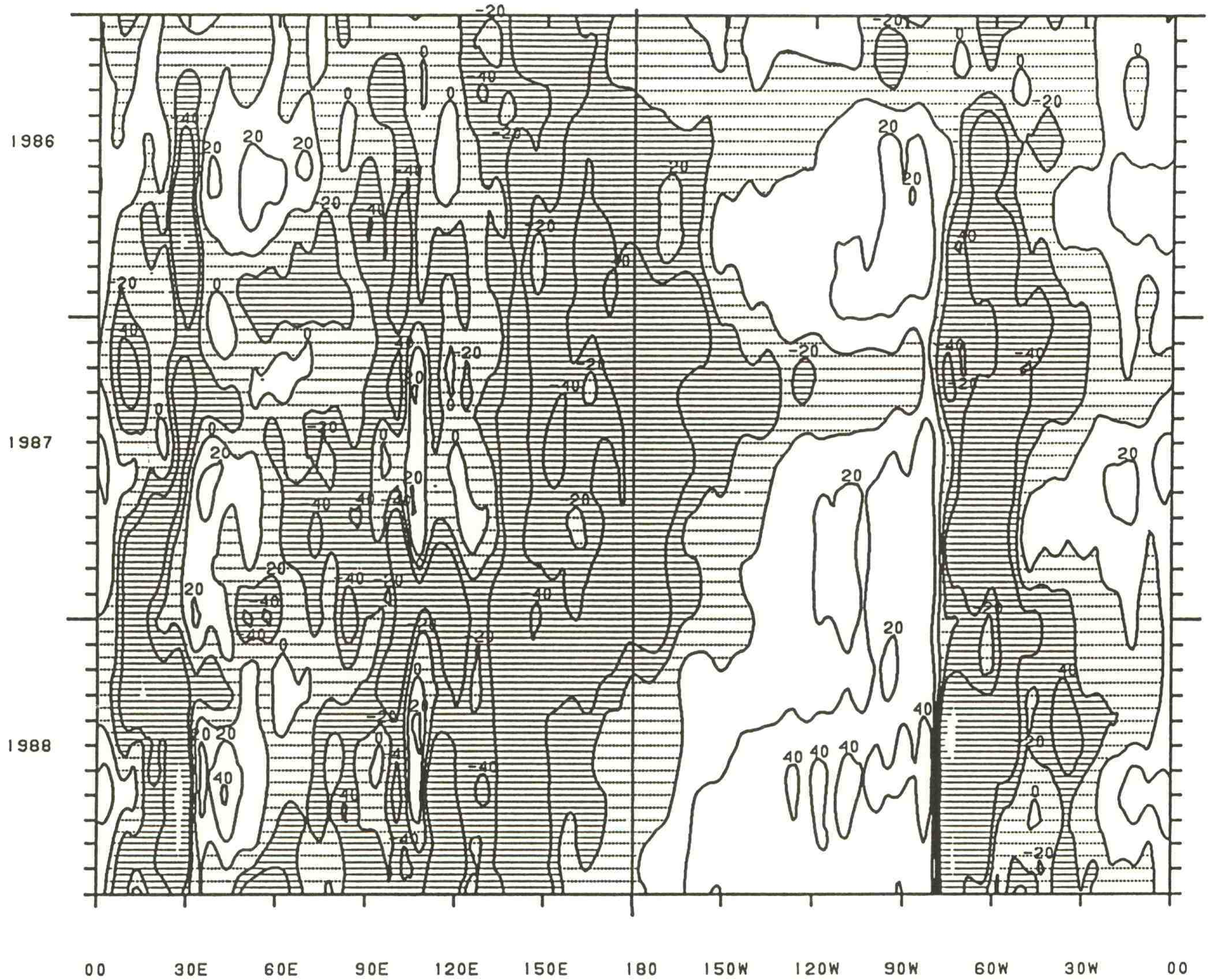


Figure 19 Time-longitude diagram (7.5°N - 7.5°S) of vertical velocity (mb/s x 10^5) at the 500 mb level from the NMC/MRF model during 1986-88.

Figure 20 Time-longitude diagram ($6.25^oN - 6.25^oS$) of satellite-derived rainfall estimates (mm/day).

A follow-up study was initiated for the July 1989-July 1990 period, which encompasses 73 pentads (5-day periods). A comparison was made between satellite-derived rainfall estimates and 0-6 hour and 12-36 hour precipitation forecasts from the MRF model in the tropics. Initial results indicate that the model-forecasted values are greater than the satellite rainfall estimates over the oceans, while the reverse seems to be the case over land. The mean pattern correlation among the 73 pentads is 0.54 for the GDAS precipitation forecasts and 0.49 for the 12 to 36 hour model forecasts.

2.3 Atmospheric Circulation

2.3.1 Tropospheric Anomalies (Janowiak, Kousky)

Monthly rainfall anomaly maps, based on a 1979-1988 base period, are now being produced routinely (figure 21). These maps are formed by applying the GPI rainfall estimation method on histograms of OLR flux from the NOAA 10 and 11 polar orbiting satellites to obtain monthly rainfall. The anomalies are then computed by subtracting climatological rainfall estimates derived from an estimation technique that uses mean OLR flux. These charts are now being examined to ensure their reasonableness, and if acceptable, will be included in CAC's Monthly Climate Diagnostics Bulletin.

2.4 Operational Products

2.4.1 Climate Diagnostics Bulletin (Kousky)

The printing and dissemination of the Climate Diagnostics Bulletin (CDB) has been accelerated in the past year. The CDB is prepared at CAC and then delivered to the Department of Commerce for printing and mailing which now takes only one week. This improvement in turn-around time enables the CDB to reach users around the 20th of each month, which is about 10 days faster than the year before. In another development that enables CDB users to receive advance information, selected tropical Pacific indices and a preliminary text are both transmitted on OMNET before the tenth of each month.

2.4.2 Seasonal Climate Review

2.4.2.1 September - November 1989 (Halpert)

Atmospheric and oceanic conditions throughout the tropical Pacific continued to be near normal during this season. Tropical Pacific sea surface temperature (SST) anomalies hovered within 0.5^{o}C of normal. The outgoing long-wave radiation (OLR) index for November was negative (above normal convection) for the first time since early 1988. The increase in convective activity near the date line was associated with low-level convergence. Also, the westerly 850 mb zonal wind anomalies in the western Pacific marked the first such occurrence since the end of the 1986-1987 El Niño/Southern Oscillation.

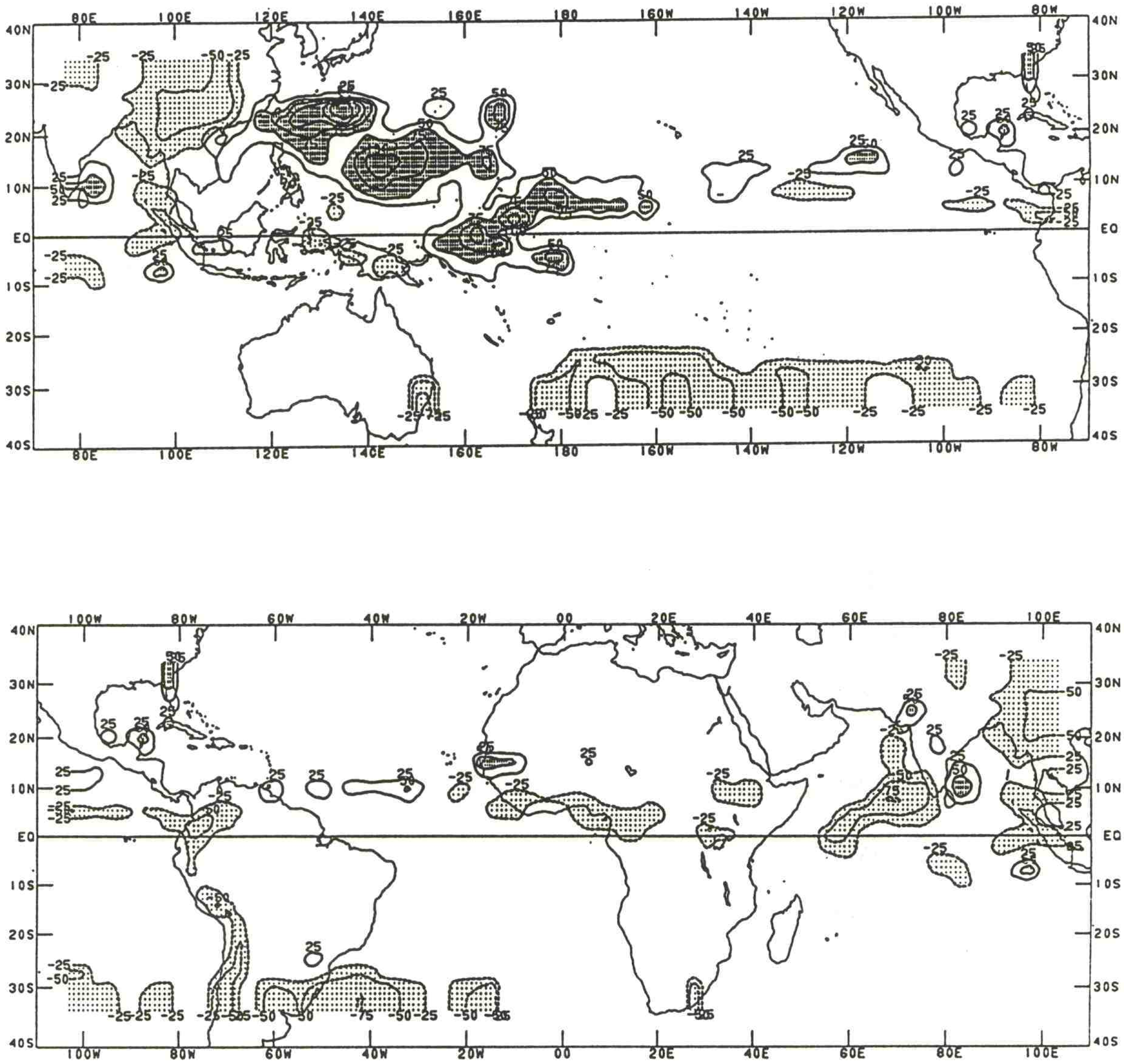


Figure 21 Estimated rainfall anomalies (mm) for August, 1990, derived from observations of OLR flux from the NOAA polar orbiting satellites. The base period for the anomaly values is 1979-1988.

The 1989 Atlantic hurricane season ended with seven hurricanes and 11 named storms, slightly above the long-term mean. The most notable of the hurricanes was Hugo, which struck the South Carolina coast in September. This was the most intense hurricane to hit the United States mainland since Hurricane Camille in 1969. Precipitation percentiles during the season were generally close to normal throughout the Northern Hemisphere, although the rainy season in the Pacific Northwest began slowly. This is significant since the last three rainy seasons in this region have been deficient.

2.4.2.2 <u>December 1989 - February 1990</u> (Janowiak)

In the western tropical Pacific, the Southern Oscillation Index (SOI) was negative for each month. Weaker than normal 850 mb easterly winds were observed over the western equatorial Pacific and negative outgoing longwave radiation anomalies (above normal convection) were observed east of the date line for the first time since early 1988. Although sea surface temperatures were not strikingly high in the tropical Pacific, an impressive buildup and eastward propagation of sub-surface warm water was observed.

Extreme contrasts in monthly mean temperature were observed during this season over much of North America. While December 1989 was the 4th coldest (since 1895) December for the contiguous United States, it was followed by the warmest January and the 15th warmest February. Most of Europe also experienced a very mild winter, although several intense storms with gale force winds occurred over the northern and western portions of the continent.

2.4.2.3 <u>March - May 1990</u> (Kousky)

Signs of a developing warm episode in the tropical Pacific, which appeared during December 1989-February 1990, became less coherent during this season. Sea surface temperature (SST) anomalies remained near $0.5^{o}C$ in (the central equatorial Pacific region) and increased to near $0.5^{o}C$ in the eastern equatorial Pacific by the end of May. These anomalies are about $1^{o}C$ higher than those observed during March - May 1989. The Southern Oscillation Index rose sharply throughout the season and ended with a positive value. The 850 mb zonal wind index in the western Pacific, as well as the outgoing longwave radiation index, also trended towards zero (normal).

The pattern of warm weather, which occurred in the Northern Hemisphere extratropics during January and February 1990, continued and intensified in March. Nearly all of North America, Europe and the Soviet Union experienced temperatures above the 70th percentile. Some regions, such as Siberia, northwestern North America and western Africa experienced abnormally warm temperatures throughout the season. Western Europe, on the other hand, experienced temperatures much above normal during March and May, but near normal in April.

2.4.2.4 June - August 1990 (Ropelewski)

Equatorial sea surface temperatures continued to move towards warm episode conditions in the central Pacific during this season. However, analogous warm conditions did not occur in the traditional eastern Pacific El Niño areas. The central Pacific warming was supported by above normal convection near the dateline; but none of the global atmospheric teleconnection patterns, generally associated with warm episodes, made their appearance.

Dry conditions returned to the Sahel region, even though the general monsoon circulation progressed in a relatively normal fashion. After two years of near normal precipitation, the Sahel had its driest April to September rainfall since the record dry year of 1984. The remainder of the Northern Hemisphere summer monsoon regions experienced a mixed season with the Indian summer monsoon rainfall appearing to be about normal overall. The summer monsoon in China started with excessive rainfall amounts but closed the season dry in southern regions. Dry conditions also prevailed in the southeastern United States and over most of western Europe.

The Northern Hemisphere summer temperature continued a string of above normal values over most of the land areas; however, anomalies were generally less extreme than in the March through May period. In the Southern Hemisphere, temperature anomalies tended to show more spatial and temporal variability than in the Northern Hemisphere. In general, eastern and southern Australia experienced below normal temperatures as did the Grand Chaco area of Paraguay, Uruguay and Argentina. The rest of the land areas showed positive temperature departures for the season.

2.4.3 Monthly Climate Diagnostics Briefings (Diagnostic Branch Staff)

Monthly climate diagnostics briefings were presented for September-November 1989 (by M. Halpert), for December 1989-February 1990 (by J. Janowiak), March-May 1990 (by V. Kousky), and June-August 1990 (by C. Ropelewski).

3. OCEAN CLIMATE ANALYSIS

3.1 Ocean Diagnostics and Monitoring

3.1.1 OMAS Development (Leetmaa)

Major activities were focused on developing a climate data assimilation system (CDAS) for the ocean and implementing a prototype coupled model system. Under the CDAS activity, the Pacific model domain was extended to cover the area from 120E to 70W and 45S to 55N. This model now includes bottom topography and ocean thermal data are now being assimilated throughout this domain. The Pacific model system has been transferred from the CYBER to the CRAY computer.

Also, a global ocean analysis system, as developed at NOAA/GFDL, was implemented on NMC's CYBER 205 in January 1990. Since then, routine weekly analyses are performed in parallel with the Pacific basin analysis system. With the procurement of CRAY computers at both NMC and GFDL, the decision was made at GFDL to develop an up to date global ocean code for the CRAY. This new version will be made available to CAC shortly, which will greatly facilitate testing of physical parameterizations.

Furthermore, a coupled model system has been implemented first on the CYBER 205 and then on the CRAY. This system consists of an active Pacific Ocean model, with climatologically varying global SSTs, coupled on a 12-hour basis with a low resolution version of the operational atmospheric model. First experiments have just been conducted, and although there are some problems, the outlook for having this system perform properly is encouraging. Over much of the basin the flux imbalances between the ocean and atmosphere are small, for example, the net surface heat flux from the atmospheric model compared to the heat fluxes required to force the ocean model.

As part of CDAS, considerable efforts have gone into improving the quality control procedure for the different ocean data sets. Interactive procedures were developed that assign proper call signs to unidentified platforms, correct erroneous positions and times, and evaluate individual profiles in the context of groups of profiles taken by the same ship. It has been found that the largest source of error, by far, is in the temperature estimate itself. Currently, 25% of the reports are being rejected because of poor thermal data, compared to 5% for all other problems. Most of the development work on the interactive editing procedures has been for the Pacific basin. This is now in the process of being extended to the global domain.

3.1.2 Tropical Surface Fluxes (Leetmaa, Reynolds, Marsico)

A major activity of ocean studies is the evaluation of surface fluxes from the NMC atmospheric model. CAC maintains separate flux archives of the operational runs and other low level atmospheric model fields. These are evaluated by direct intercomparisons to observations, comparisons to estimates of the net surface heat flux from the ocean analysis system, comparisons with climatological fields, and assessing their appropriateness for forcing the ocean model. To date, an examination has been made of momentum, heat, moisture and fresh water fluxes. Results for the tropical Pacific show that the stress field from the operational atmospheric runs appears to be "reasonable".

An examimation of the surface heat fluxes, however, indicates a number of problems. On the eastern sides of the basin, the net short wave flux was significantly larger than that indicated from climatological estimates. Recently tested changes to the cloud parameterization, which allow for a lower cloud base, have reduced this problem. Overall in the 20N to 20S zone, the atmospheric net heat flux appears to be about 40 watts/m2 higher compared to climatology and the estimates from the ocean analysis system. This bias appears to be caused by an overestimation of the short wave flux and an underestimation of the evaporation. Initial experiments with a coupled ocean-atmosphere model indicate that fluxes from this model agree much better with estimated values from the ocean analysis system than the values from the operational analyses.

An evaluation is also being conducted of the oceanic rainfall derived by NMC's global atmospheric model. Comparisons with climatological fields and those estimated from satellite-derived outgoing long wave radiation indicate that the model estimates are of the same order of magnitude as the other fields. A task is now underway that employs the fresh water flux from the atmospheric model and use it as a forcing field for the ocean.

3.2 Operational Products

3.2.1 Ocean Monitoring (Leetmaa)

Although sea-surface temperatures (SST) remained anomalously cool or close to normal in early 1990, the volume of warm subsurface water in the equatorial zone (thought to be a necessary condition for an El Niño to occur) remained anomalously large. As the year progressed, positive SST anomalies started to appear, and late in the year, positive anomalies of 1-2^{o}C were situated in the equatorial zone near the dateline. In the meantime, SST values in the near equatorial eastern Pacific remain close to normal.

3.2.2 Tropical Pacific Nowcasting (Leetmaa)

Changes in the model domain have in turn, changed some of the ocean products which could no longer be used. For example, a proper basin-wide climatology was lacking. Consequently, new products had to developed for thermocline depth, integrated heat content, sea surface temperature, and their departures from climatology. Some of these revised products are now being inserted in CAC's Climate Diagnostics Bulletin.

4. STRATOSPHERE AND TRACE GASES

4.1 Field Analysis

4.1.1 Stratospheric Winds (Miller)

A comparison was made between CAC's stratospheric analyses (70-10 mb levels) and those produced by the parallel Medium Range Forecast (MRF) model. The parallel MRF analyses were improved over the operational MRF analyses; however, the height and temperature fields still have larger mean errors than CAC's analyses. Evaluation of the results of extending the MRF up to 10 mb has been delayed due to implementation of the computer code onto the CRAY system. It is anticipated that parallel processing will be resumed for the Northern Hemisphere winter.

4.1.2 ERBE Analysis (Yang)

In this study, ERBE-derived net earth radiation values are being used to examine the energy transport between the atmosphere and ocean. Based on net radiation values, the necessary energy transport was calculated for April, July, and October 1985, as well as January 1986. These calculations were compared with energy transport values derived from NMC global wind component and height analyses. The results show that the ERBE values and NMC analyses agreed in mid-latitudes, but not in the tropics. It was also found that the storage term and ocean transport dominate the seasonal variation.

In a related study, attention is being focused on the role of cloud amount and cloud type in the climate system. A joint evaluation (with NESDIS) of the operational NOAA/TOVS cloud product has resulted in an improved understanding of the data characteristics. Also, an intercomparison was made between NOAA/TOVs data and other satellite cloud data sets derived from real-time neph-analyses (USAF), ISCCP, and NASA/TOVS. Preliminary results indicate that the NOAA cloud retrieval algorithm underestimates high cloud and overestimates low cloud amounts. A number of suggestions on ways to refine the operational system are being examined..

4.1.3 Upper Air Intercomparisons (Gelman)

The final report on the Baseline Upper Air Network (BUAN) test was completed (in cooperation with personnel from NESDIS and National Weather Service) and submitted to the WMO for publication. The BUAN test (January - July 1988) involved a select group of radiosonde stations from countries, who provided special observations scheduled to coincide with the overpass of NOAA 10 satellite. Results showed that the BUAN data were superior to conventional radiosonde data for use in evaluating the results of the satellite-derived temperature retrievals. However, no improvement was demonstrated by the BUAN data over conventional radiosonde data when used as input to regression coefficients. The major contribution of the BUAN test is an archive of NOAA-10/TOVS data and coincident BUAN radiosonde data, which will be used to further explore methods to improve satellite retrievals.

Special support and information continue to be provided to NASA/Houston in connection with Space Shuttle landings. Data from rawinsondes, rocketsondes and NMC analyses are used to derive detailed estimates of atmospheric parameters from 400,000 feet to the surface along the reentry path of each shuttle flight. These data were utilized to support 5 Space Shuttle landings at Edwards AFB, CA during the year.

4.2 Ozone/Temperature Trends

4.2.1 Ozone Trend Analysis (Nagatani)

A major focus has been on the evaluation of the NOAA-9 SBUV/2 operational satellite ozone data and a subsequent revised data set. The revision was made after tests showed a drift in the upper level information in the original data set. Figure 22 shows the percent difference between SBUV/2 minus ground-based Dobson data for the two data sets. So far, the data have been revised only for the first two years, but it is clear that there has been a major impact on the derived satellite data. As the data are reprocessed, further evaluation will be conducted in regard to possible change in time.

4.2.2 Temperature Trends (Miller)

A statistical program was developed (by the University of Chicago, under a CAC grant) and provided to CAC to evaluate global temperature and ozone trends from NMC stratospheric analyses (1978-present). Included in this statistical time series analysis is a relationship between temperature and ozone with solar flux variability and the QBO cycle, together with the annual and semi-annual cycles. There is also a noise (error) component, which is auto-correlated over time and modeled as an auto-regressive process. The data for all components have now been archived in this joint study with the University of Chicago, the University of Wisconsin, and Lawrence Livermore Laboratories.

A pilot study has been completed to evaluate possible trends in stratospheric temperatures from 1978-1990. Results show an apparent correlation between the solar cycle, as indicated by the F10.7 solar flux and upper stratospheric (1 mb and 2 mb) equatorial monthly mean temperature. The indicated solar cycle-related temperature change is about 1.5^{0} C, superimposed on an overall decrease in temperature of about 1.5^{0} C, peaking near 1 to 2 mb.

4.2.3 Stratospheric Climatology (Nagatani)

A climatological study for the Airborne Arctic Stratospheric Expedition was completed, in which lower stratospheric temperatures during January - March 1989 were compared with temperatures available since January 1964. Results show that the averaged temperatures for January 1989 were the lowest values for any January in the last 26 years at high latitudes. Lower stratospheric temperatures for February 1989 were higher than average, while March 1989 had some of the highest polar vortex temperatures in the last 26 years. Consequently, conditions were not very favorable for polar stratospheric cloud formation into early spring. In an extension of this study, the compiled data are now being used to analyze ozone trends (See Section 4.2.1).

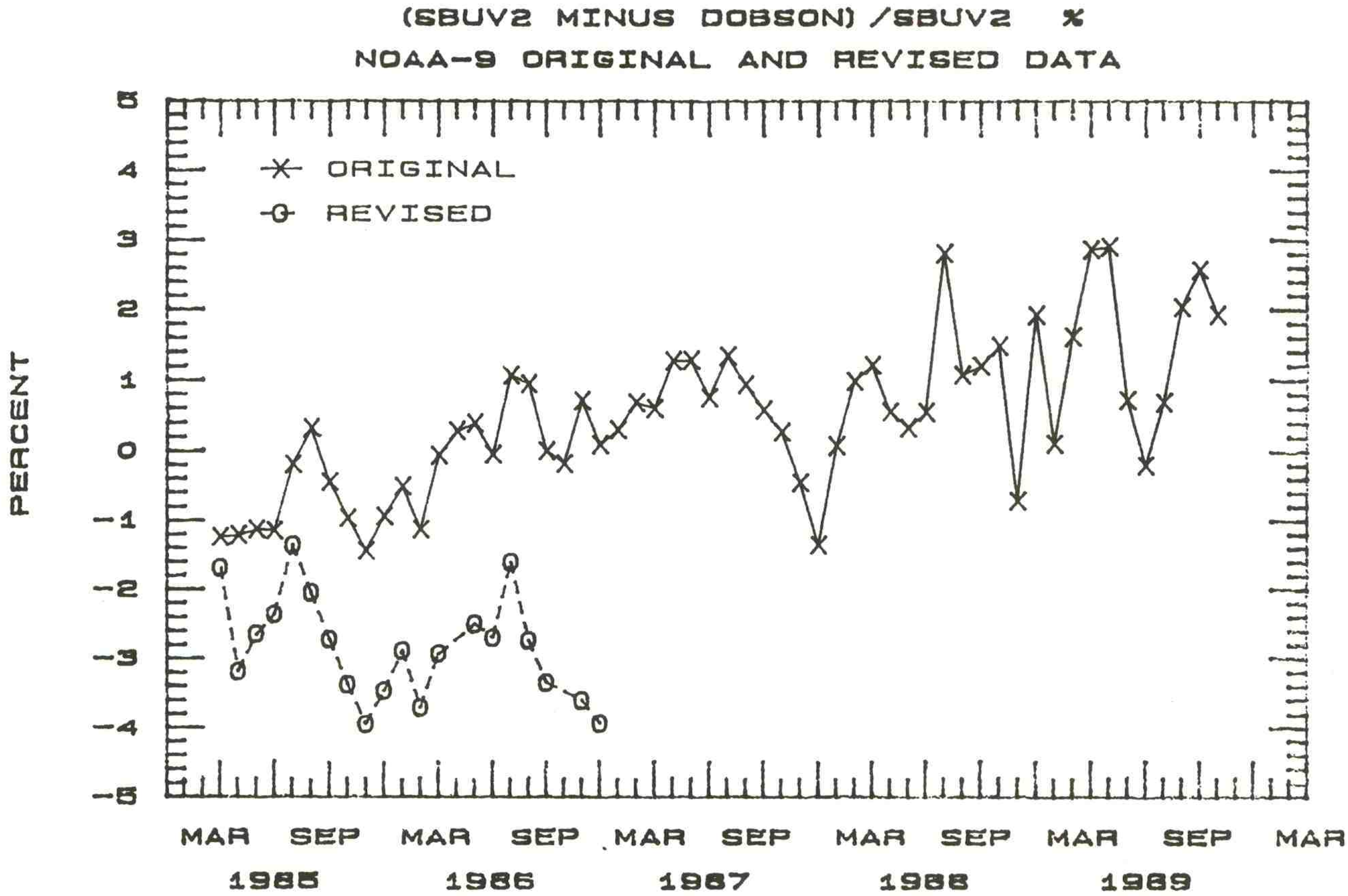


Figure 22 SBUV/2 ground/based Dobson data comparisons.

4.3 Operational Products

4.3.1 Circulation/Temperature Analysis (Gelman)

Lower stratospheric temperature conditions continue to be of special interest, in connection with the "ozone hole" over Antarctica. Stratospheric maps for the Southern Hemisphere were disseminated daily in support of research efforts in Antarctica. Figure 23 shows that 50 mb zonal temperatures at 80S are near the long term average, which is consistent with reported near record low ozone values over Antarctica.

In the Northern Hemisphere, a major stratospheric warming in early February 1990 led to a circulation reversal in the upper stratosphere down to about 30 mb. By mid-February, at 50 mb, Arctic temperatures returned to below the long term average, as had been observed for most of the winter. Interest is keen because low stratospheric temperatures play an important role in the formation of polar stratospheric clouds, which in turn affect stratospheric ozone depletion in the winter-spring polar vortex of both hemispheres.

4.3.2 Atmospheric Angular Momentum (Miller, Kann)

The official beginning of the Sub-Bureau for Atmospheric Angular Momentum, under auspices of the International Earth Rotation Service, started on October 1, 1989. The purpose of the Sub-Bureau (located at NMC) is to compare analyses and forecasts of atmospheric angular momentum computed by National Weather Service stations, and to provide evaluations to the international community. Data are now being received from the U.K. Meteorological Office and the Japan Meteorological Agency with a link to the European Centre to be established shortly. Evaluation of the data is being performed jointly with the Jet Propulsion Laboratory and the Atmospheric and Environmental Research Inc.

4.3.3 Ozone Analysis (Nagatani)

NOAA 11-SBUV/2 data are being compared with total ozone data from two other satellites--NOAA-11/TOVS and Nimbus 7/TOMS. These comparisons are being conducted during the Southern Hemisphere spring, as the Antarctic "ozone hole" is being monitored with as many as three of the instruments on a given day. Initial results show that the NOAA-11 SBUV/2 data compare favorably with NOAA-7 TOMS data. Even though the coverage for SBUV/2 is less than that from TOMS, many of the features shown by the TOMS data are also shown by the SBUV/2 data.

In another task, preparations are being made for NASA's UARS satellite. Software was developed and is being made available to scientists at NASA/Goddard to access and obtain NMC profile and gridded data in near-real-time. Plans are being developed for a daily transfer of NMC data to Goddard, after tests are performed on limited data sets.

Meteorological profiles continue to be provided to support NASA's SAGE II and SAM II satellite instruments. These data are being used to retrieve stratospheric profiles of aerosols, ozone, water vapor, and nitrogen dioxide. The ozone retrievals from the SAGE II instrument are being made available to CAC to compare them with NOAA-9 SBUV/2 data.

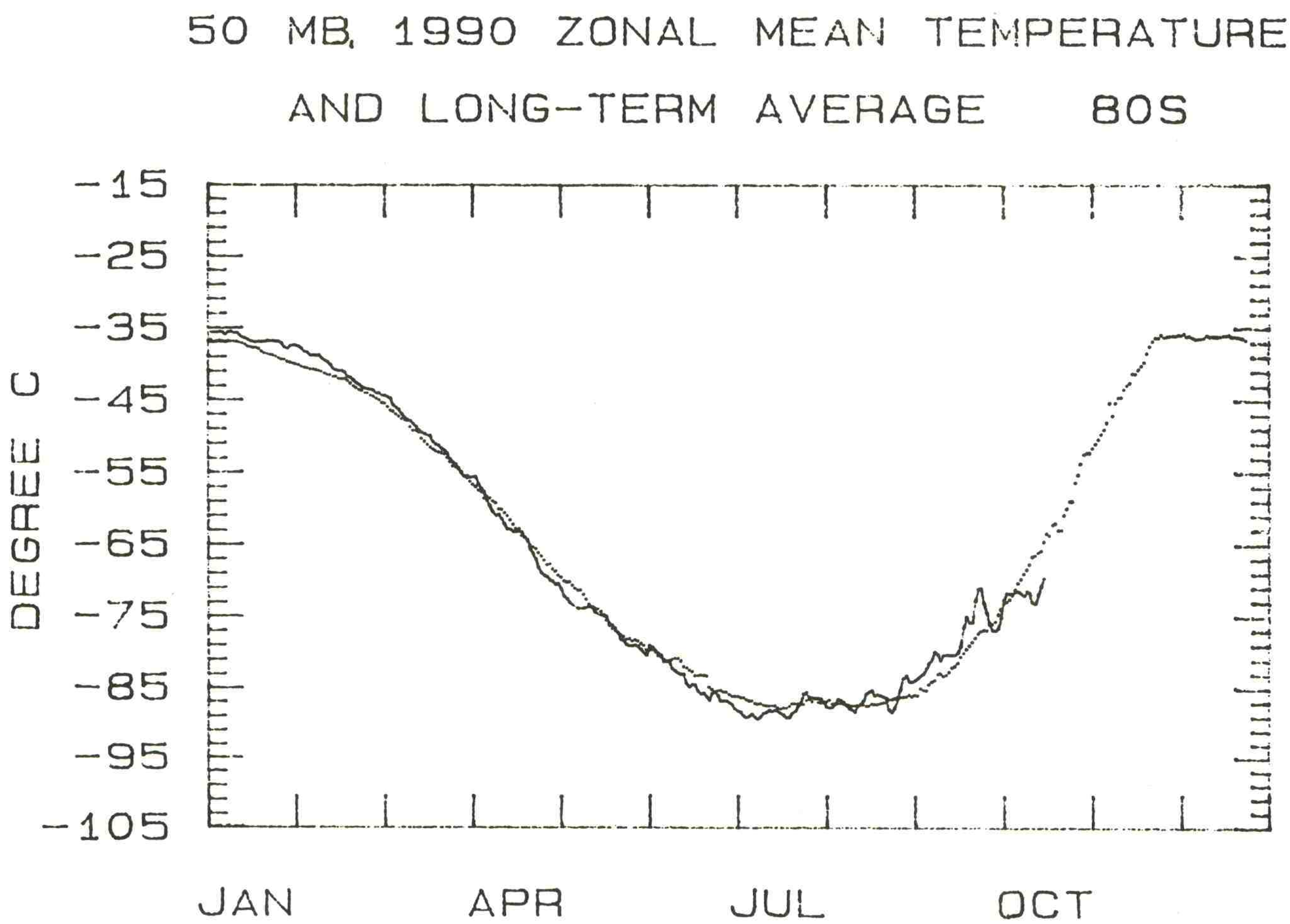


Figure 23 50 mb zonal mean temperature at 80S for 1990 (solid line) and long-term average for October 1978 - October 1990 (dotted line).

THIS PAGE INTENTIONALLY LEFT BLANK

5. APPLIED CLIMATOLOGY

5.1 Surface Data

5.1.1 Surface Climate Assessment (Miskus)

Many areas of the world experienced precipitation extremes during the last 4 seasons, as shown by figure 24. In the United States, October and November were excessively dry in the Central Plains; while in December, California and parts of the Pacific Northwest observed record dryness. Although precipitation increased markedly in the latter region during January-March, southern California recorded its fourth consecutive subnormal rainy season. During late April and early May copious rains produced severe flooding in the south-central Great Plains, while heavy late Spring rains and numerous severe weather outbreaks afflicted much of the Midwest. In contrast, a lack of significant tropical convection caused dryness along the eastern Gulf and south Atlantic Coasts during summer and early fall.

In Europe, dry weather occurred from the Iberian Peninsula eastward into Italy during October. Much of southern Europe was also dry during December-February and again during May-September. However, torrential November and December rains produced severe flooding in southern Spain and northern Morocco. Also, a series of intense mid-winter storm systems caused widespread flooding, coastal erosion, and extensive property damage in northwestern Europe.

In the Far east, an active 1989 and 1990 tropical season produced ample rains for most of eastern China, Taiwan, southeast Asia, Japan, Korea, and the Philippines. While the 1990 Indian monsoon season brought generous and sometimes excessive rains to most areas, the African Sahel rainy season, after two successive near-normal years, returned to much drier conditions.

In the Southern Hemisphere many countries experienced a wet November, followed by a near-record dry December-February. However, heavy rains in late January and early February produced flooding in Indonesia and northwestern Australia, and near-record March and April rainfall occurred in northeastern Australia. Also, the rainy season in southern Africa got off to a wet start. In South America, ample rains in late 1989 into early 1990 occurred in most of Brazil, Uruguay, northern Argentina, and Paraguay; however, during June-August it became unusually dry in Uruguay and Argentina.

Significant Northern Hemisphere temperature anomalies were mainly positive. One exception was in December when bitterly cold Arctic air, which settled over Alaska and Canada during November, invaded the eastern halves of Canada and the United States. However, in January record warmth then pushed into southern Canada and the U.S. where it persisted into February. Europe experienced above normal temperatures in January and February, and warm conditions also developed during February in the western Soviet Union and northeastern China. In March, hundreds of stations set record high monthly temperatures as exceptional warmth stretched across much of Europe, northwestern Africa, Asia, and North America. During April and May, warm weather persisted in northern Europe, parts of Siberia, Alaska, and the western Sahel. During the summer, above normal temperatures occurred in Alaska, central Siberia, Japan, and western Europe. During September, warm weather dominated the western and central U.S., southwestern Canada, the Sahel, and northwestern Africa.

GLOBAL PRECIPITATION ANOMALIES

SEPTEMBER 1989 - AUGUST 1990

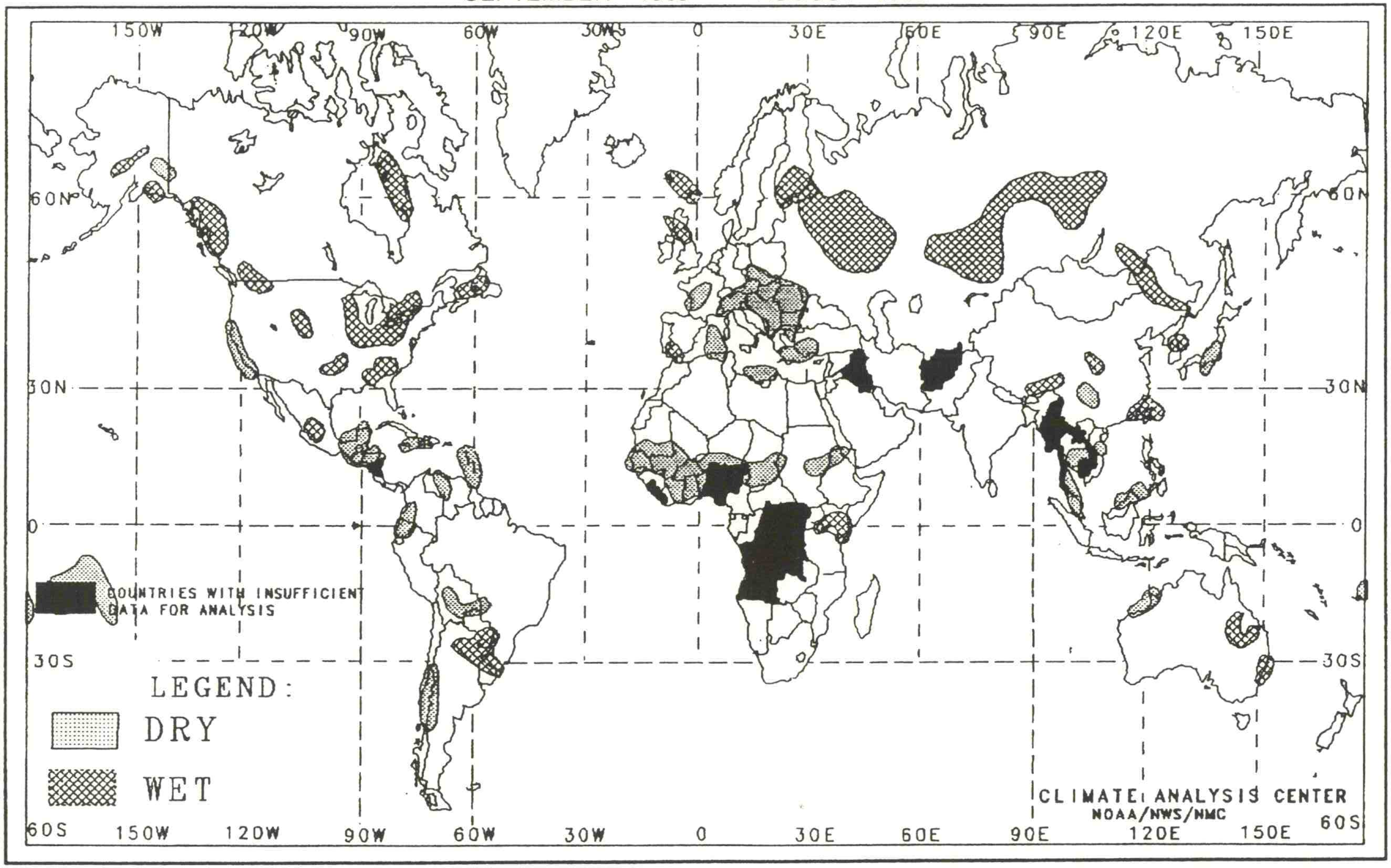


Figure 24 Global precipitation anomalies for September 1989 - August 1990. Shading depicts regions where anomalies were estimated to be within the wettest or driest 10% of climatological occurrences. (Based on 1951-1980 dataset.)

In the Southern Hemisphere, temperatures were below normal in Bolivia and Peru (October-December), in Paraguay and southern Australia (February), and in central South America (June-September). In contrast, unusual December-January warmth occurred in Argentina, Uruguay, and eastern Australia. Also, warm conditions occurred in southeastern Brazil and Australia (April), in southwestern Australia (May), in south-central Africa (June), and in Argentina (August).

5.1.2 CLICOM (Laver)

Cooperative efforts continued with NWS/Office of Meteorology to support CLICOM graphics and applications. A new version of CLICOM software was sent to experts in the United States and WMO Regional Centers for testing during August 1990. There has been a favorable response to the advanced features in the test version. However, some problems exist with memory requirements and differences between versions of commercial software packages already in use.

5.1.3 SOLRAD (Yang)

SOLRAD operations (data collection, dissemination, and processing) continued at the same level as 1989. However, the SOLRAD network will be affected greatly as the National Weather Service phases in its Automated Station Observation System (ASOS). Eight stations will be closed; sixteen will have to be relocated; and only seven stations will remain at their present locations. The sixteen stations to be relocated also face the possibility of being discontinued, due to the problem of finding a suitable new site.

5.1.4 National Climate Assessment Data Base (NCADB) (Laver)

A report was written (by Canfield, CICS; Katz, SSAI) entitled "Coop Station Data for CAC Operations." This report summarizes CAC capabilities and recommendations concerning the operational use of cooperative data to enhance the U.S. component of the Climate Assessment Data Base. The report also states that numerous variations in observation transmission and computer-processing practices, combined with data dictionary deficiencies, preclude efficient routine acquisition of non-precipitation observations from coop stations. Additional resources are now needed to make major improvements in this data base, which is limited and dependent upon the modernization of the cooperative network. Discussions have been held between members of CAC and NWS/Office of System Operations on ways "to modernize" the cooperative data network.

Exploration of independent regional data sources has created the potential for dense, high quality data over subsets of the United States. Routine access to these data through NSFNET file transfer is required before practical applications can be developed and tests are scheduled for late 1990. Meanwhile, CAC's products continue to rely on data from different sources, including the cooperative network. One example (see figure 25) shows accumulated precipitation data which confirms the extent that both short- and long-term dryness abruptly ended in the southeastern United States .

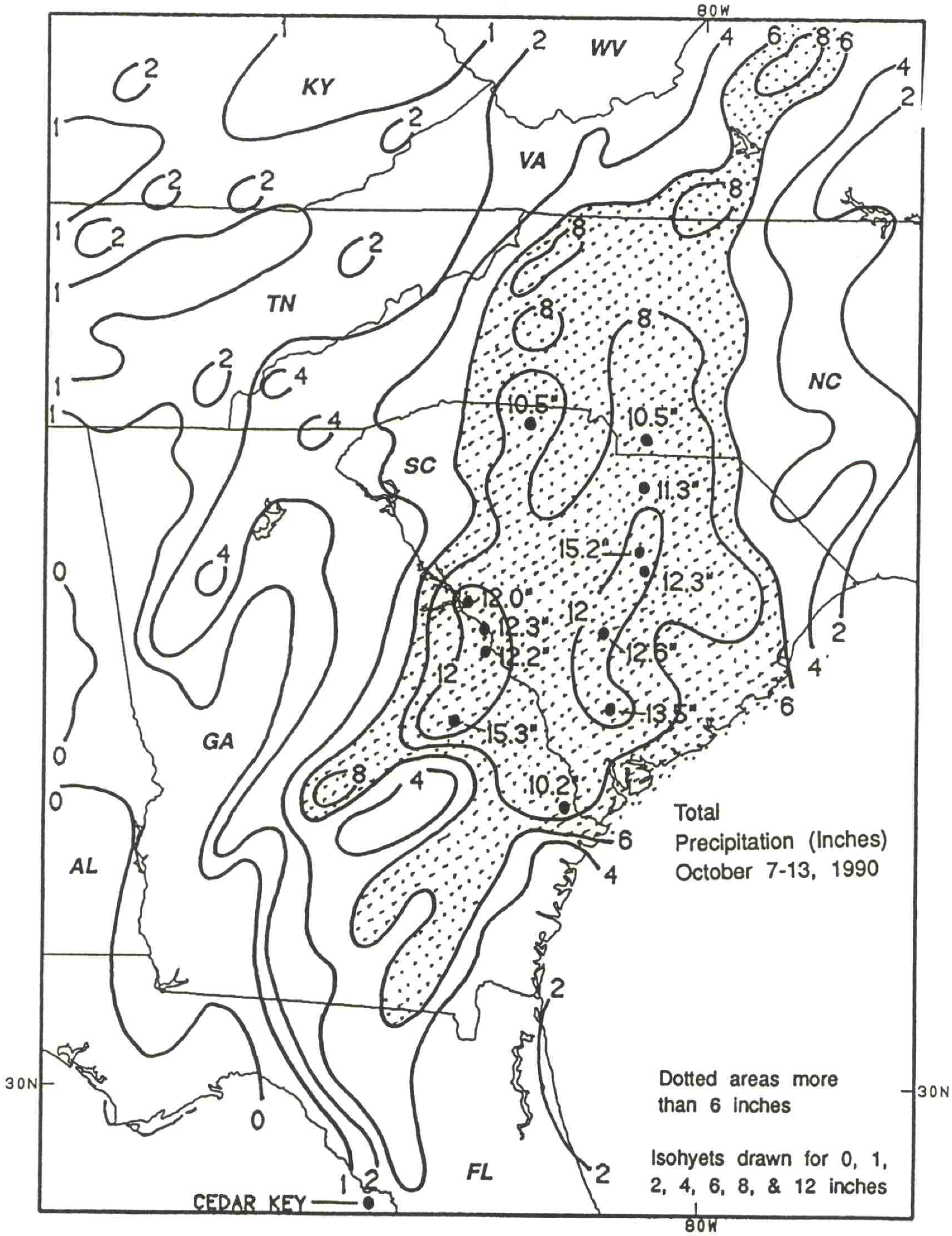


Figure 25 Accumulated precipitation data from first-order synoptic, airways, and River Forecast Centers stations. The precipitation is from a sequence of tropical storm remnants and a stalled cold front.

5.2 Agricultural Applications (JAWF)

5.2.1 Climate/Agricultural Assessment (Le Comte)

World crop production is reaching new heights, so far, in 1990. Canada, China, and India are setting grain production records and the United States and the Soviet Union are having excellent crops. A mild winter and spring as well as plentiful summer rainfall in major mid-latitude crop areas of the Northern Hemisphere contributed to the bumper crop yields, as did a successful southwest monsoon season in South Asia. In addition, the Southern Hemisphere's two major wheat-producing countries, Argentina and Australia, had timely rains and very good harvest prospects. The result was a USDA forecast (1990/91) for world grain production to reach 1.76 billion tons. This exceeds the previous record set in 1986/87 by 5 percent and represents a 22 percent increase in just the past 10 years.

5.2.2 Africa; FEWS Project (LeComte)

CAC's Agricultural Weather Section again closely monitored rainfall during the African growing season in support of the Agency for International Development's Famine Early Warning System (FEWS). For the first time, automated contoured rainfall and temperature maps were transmitted to AID/FEWS during the summer of 1990. These maps (developed by A. Herman, Ellsworth Assocs.), combine observed surface rainfall with satellite-derived rainfall estimates based on OLR data. The three principal products--maps of 10-day rainfall totals, percent of normal rainfall, and temperature departures--are used to help assess the extent of dryness across the Sahel zone of Africa. Figures 26 and 27 show sample plots/analyses of rainfall over western and eastern Africa respectively.

Weekly descriptive summaries of central African weather as well as the daily location of the Intertropical Convergence Zone (ITCZ) were also provided to AID. The 1990 rainy season was mediocre for Sahelien agriculture with rainfall totals generally less than in 1989 and 1988. The main concern was the Sudan, where drought likely had a major impact on rain-fed agriculture and subsistence food production. Agricultural Weather Section products, such as surface temperature and the ITCZ location (based on dewpoint temperatures), helped confirm the dryness in sparse data areas.

5.3 Climate Impacts: Monitoring

5.3.1 Products for Impacts Evaluation (Laver)

CAC produced a Report entitled "Climate Assessment for 1989 - Selected Indicators of Global Climate." This publication was distributed to several hundred users in March 1990. Feedback from readers included a number of suggestions that will be considered in preparation of a climate assessment for 1990. Also, plans are being coordinated with the National Climate Data Center and other NOAA Laboratories for a more ambitious publication - a Climate Assessment for the 1981-1990 Decade.

TOTAL PRECIPITATION
AUG 21 – 31, 1990
WESTERN AFRICA

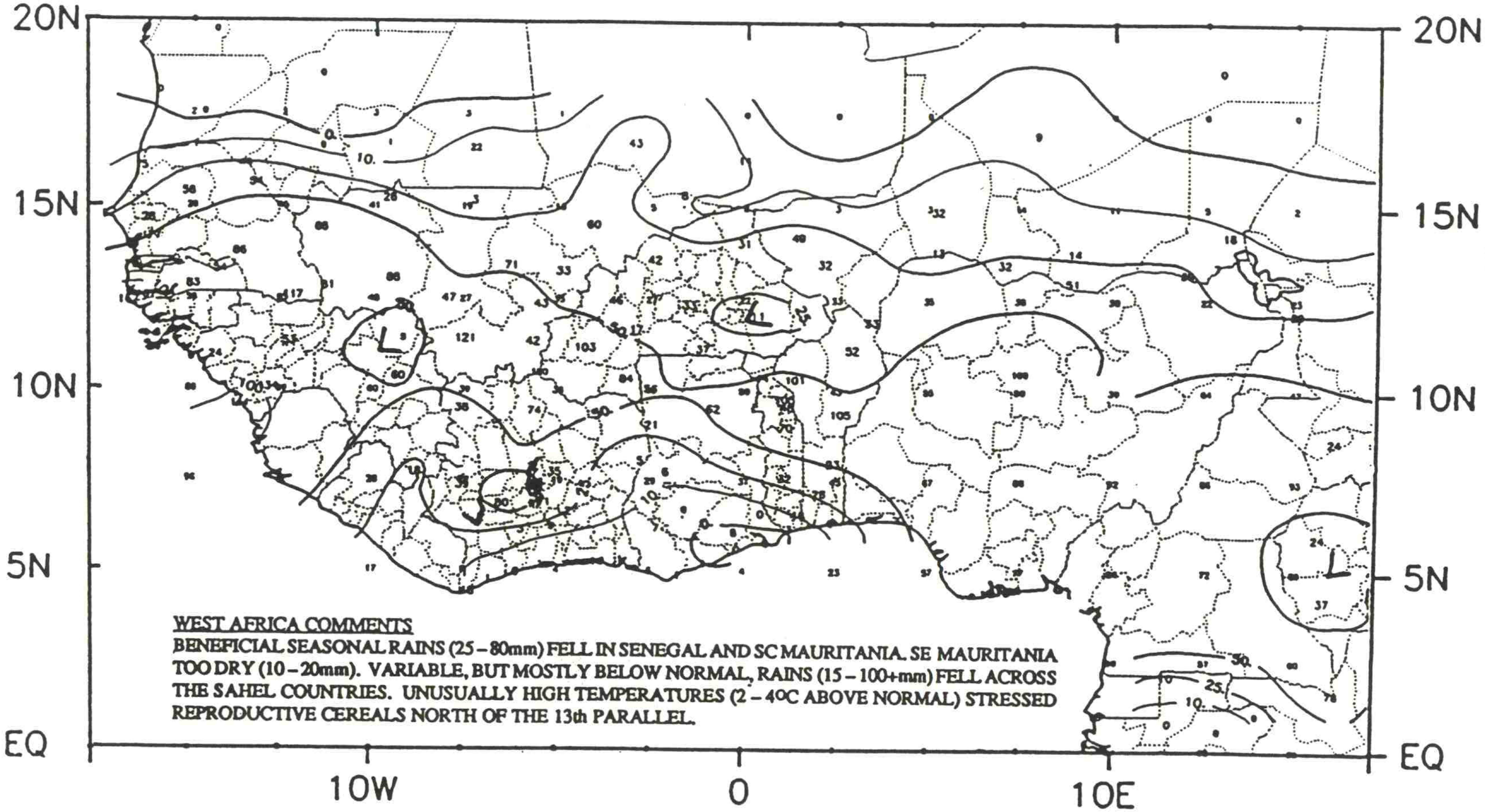


Figure 26 Western African Sahel precipitation estimates (mm) and comments for August 21-31, 1990 using synoptic rainfall reports and estimates based upon NOAA satellite OLR data. The figure was created on the Apollo system and transmitted to AID's Famine Early Warning System.

TOTAL PRECIPITATION
AUG 21 – 31, 1990
EASTERN AFRICA

EAST AFRICA COMMENTS

AGAIN, HOT AND UNUSUALLY DRY ACROSS NORTHERN CROP AREAS IN SUDAN. TEMPERATURE ANOMALIES NEAR +5°C IN KHARTOUM–SENNAR–KASSALA AREA ARE VERY UNUSUAL ANYWHERE IN THE TROPICS. RAINFALL OF 0 – 25 mm IN THE NORTH WAS WELL BELOW NORMAL AND FAR SHORT OF PLANT MOISTURE NEEDS. MODERATE TO HEAVY RAINS (50 – 100mm) MAINTAINED GOOD GROWING CONDITIONS FOR CROPS IN THE SOUTHERN MECHANIZED SOURGHUM ZONE (RENK–DEMAZINE). SPARSE DATA STILL SUGGEST BELOW NORMAL RAINFALL IN NORTHERN AND EASTERN AREAS OF ETHIOPIA. HEAVY RAINS IN THE WEST HELPED TO SET THE STAGE FOR THE FLOODING REPORTED AROUND GAMBELA IN EARLY SEPTEMBER. HOT, DRY WEATHER IN EASTERN SAHELIAN CHAD (0 – 25mm) HARMED CROPS AND PASTURES.

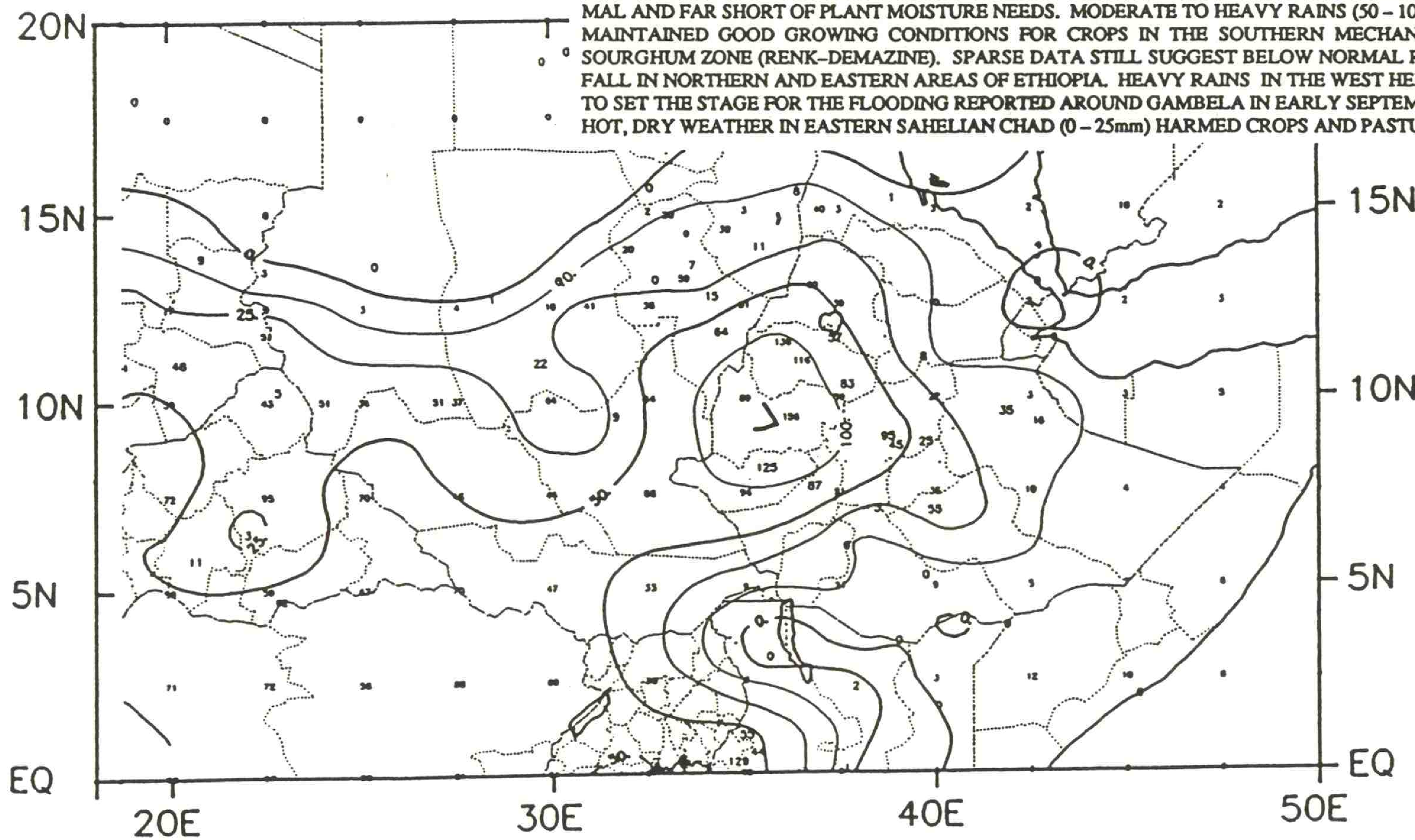


Figure 27 Same as figure 26, except for the eastern African Sahel.

Several special climate products and updates were generated in response to high-level requests for current national "items of interest." An example of one item is the long-term western drought combined with the southwest heat wave and forest fire outbreak as shown in figure 28.

5.3.2 Socioeconomic Impacts (Lehman)

Interactive software products that facilitate the use of CAC's 30-day Monthly and Seasonal Weather Outlooks were evaluated by potential users. As a result, new features were added, including day by day cumulative degree-day projections. The output of these products can provide users with advanced planning information and drive models that project weather-related energy use, crop yields, and water runoff. Other software was developed for applying standardized mathematical functions in modeling skewed climate data distributions. Products are being generated, for example, that can increase the accuracy of rainfall data used in crop yield projection models.

A model was developed, in collaboration with the Ohio Public Utility Commission, that shows past and current trends in customer use and conservation of natural gas. The trend model makes use of historical monthly heating degree day, natural gas sales and customer data. The output can drive prediction models and provide improved assessment of real trends, corrected for the annual weather variations that strongly influence sales. In a related task, a new predictive model for monthly natural gas sales is being tested that makes use of CAC Monthly Outlooks and current data from the trend model. The output of this model is designed to assist utility companies, as well as state and federal officials in anticipating energy demand, especially during national emergencies.

5.3.3 Regional Climate Centers (Laver)

The oversight of the Regional Climate Centers (RCC) was officially transferred from the National Climate Program Office (NCPO) to the National Weather Service (NWS), as directed by Dr. J. A. Knauss, NOAA Administrator in August 1990. As a follow-up action, a Memorandum of Understanding was signed by the Director/NCPO and the Assistant Administrator for NWS in September 1990. Thus, the RCCs, the Climate Analysis Center, and the National Climatic Data Center are entering a new era. The major challenge is to implement a consistent, yet diverse, program of regional and national climate services, coupled with development and applied research to improve these services. A minimum set of responsibilities was drafted (by S. Changnon) to establish guidelines for RCC operations and research.

Several special products were developed for specific RCCs and the Centers have rapidly developed information delivery systems tailored to customers in their respective regions. Members of the RCCs and CAC will have discussions and make presentations on data and services at the upcoming 15th Annual Climate Diagnostics Workshop (Asheville, NC, October 29 - November 2, 1990). Also, a special RCC session is planned during the AMS sponsored 7th IIPS Conference in New Orleans (January 1991). A meeting of technical and system experts from each Center will be held to discuss system problems and facilitate improvements in communication between Centers.

CLIMATE UPDATE
JULY 9, 1990

- Long-term dryness (Figure 1), in some cases persisting as long as four years (e.g., in southern California), has affected most of the southwestern quarter of the country. Many communities in central and southern California have instituted mandatory water rationing as reservoirs and rivers have dropped to dangerously low levels.
- Recent record and near-record breaking heat, with temperatures above 100°F, covered much of the same area as well as the High Plains (Figure 2). Several cities, such as Phoenix, AZ at 122°F, established all-time record highs
- These conditions, along with low humidities and gusty winds, have led to a large number of wild fires as indicated by the asterisks in Figure 2. Fires in the Tonto National Forest (in Arizona) took the lives of six fire fighters while wild fires near Santa Barbara, CA caused over $500 million in property damage.

FIGURE 1

DROUGHT SEVERITY INDEX (LONG-TERM PALMER) AS OF JUNE 30, 1990

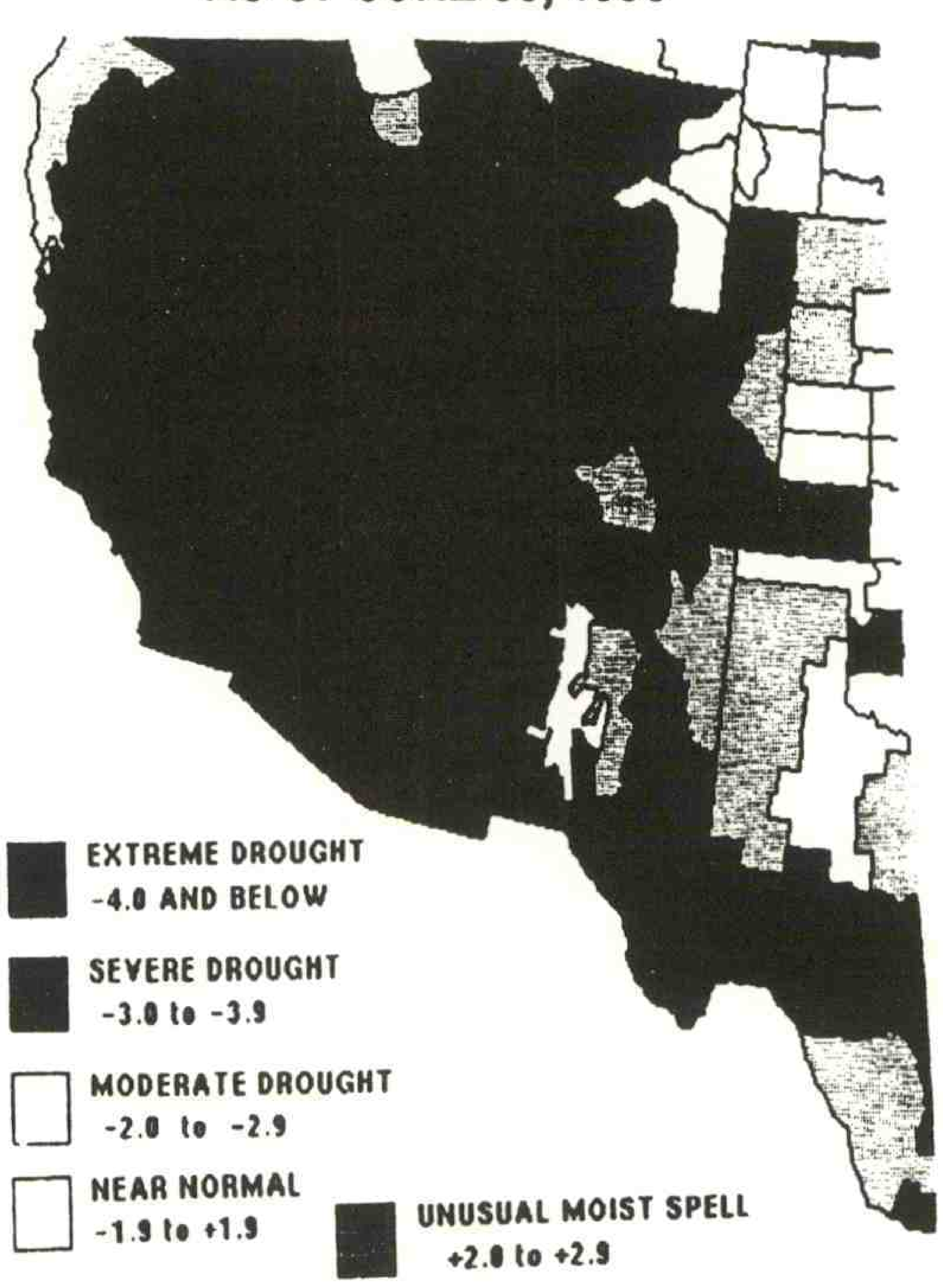
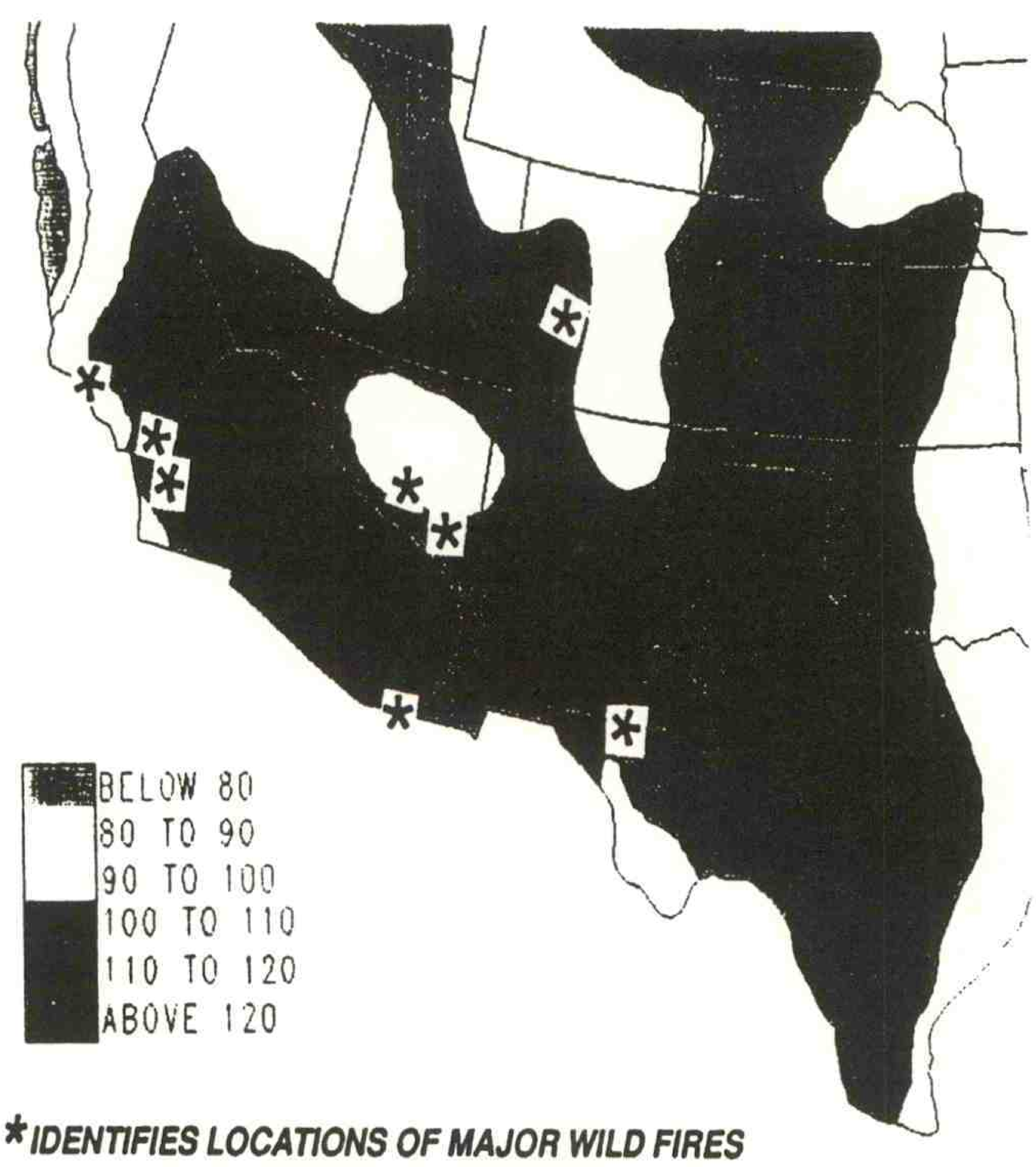


FIGURE 2

EXTREME MAXIMUM TEMPERATURE (°F) JUNE 24 – 30, 1990



**IDENTIFIES LOCATIONS OF MAJOR WILD FIRES*

CLIMATE ANALYSIS CENTER
Analysis and Information Branch

FOR MORE INFORMATION, CONTACT:
D. Miskus, J. Laver, or R. Tinker at 763-8071

Figure 28 Special climate update [normally in color] of long-term drought, heat wave, and wild fire outbreak in the southwestern U.S. during late June 1990.

5.4 Operational Products

5.4.1 Climate Dial-Up Service (CDUS) (Fulwood)

The Climate Dial-Up Service (CDUS) operation has been succesfully transferred from the Micromation system to the Microvax II computer, effective August 15, 1990. This move has been planned for over three years and affords increased processing power and disk space, automates the transfer of products from mainframe to micro, allows for product and application expansion, provides greater flexibility and reduces manual interaction. A four-month test period provided CDUS users with an opportunity to familiarize themselves with the new system and allow CAC staff to monitor system performance.

5.4.2 Daily Weather Maps (Dionne)

The production of the Daily Weather Maps has improved, with new emphasis being placed on the quality of charts produced by NMC/Meteorological Operations Division (MOD). The Daily Weather Maps series is being used as a test bed by MOD for a new InterGraph system, which will be used for all chart production. The combined effort by CAC and MOD has resulted in improvements in both data coverage and quality of these charts.

5.4.3 Weekly Climate Bulletin (Miskus)

The publication quality of the Weekly Climate Bulletin (WCB) has been improved and efficiency has increased, due to the continued use of desktop publishing software. Several pages of the WCB as well as the front cover are now produced routinely on the Apollo computer. The WCB now includes special climate-related impacts and historical meteorological data which are received from The National Climatic Data Center and some of the Regional Climate Centers. Summaries also were incorporated from the USDA's Fire and Aviation Management, the Joint Agricultural Weather Facility, and CAC's El Niño/Southern Oscillation Advisories. The number of recipients of the WCB has now increased to 1300.

During the past year there were numerous requests for information on climate anomalies. These included: the exceptional November 1989 dryness in the central Great Plains; the record dryness along the West Coast and record cold in the eastern half of the U.S. during December 1989; the abnormally mild January, February, and March across North America, Europe, and Asia; the persistent dryness in the western U.S. and southern Europe during 1990; and heavy spring and summer rains in the midwestern United States.

5.4.4 Weekly Weather and Crop Bulletin (LeComte)

The appearance of the Weekly Weather and Crop Bulletin (WWCB) continued to improve, through the use of computer and desktop publishing software. The weekly data tables for U.S. cities have been enhanced and the back cover was changed, which makes information easier to read and leaves more available space. There are now 1,200 subscribers to the WWCB, which covers the printing cost of this publication.

Special articles on significant weather events were published in the WWCB during the year. Among the topics covered were: drought in the U.S. Plains, the January 1990 severe windstorm in Europe, torrential rains in eastern Australia, wet weather in the U.S. Corn Belt, and the rash of typhoons striking China and Japan in September 1990.

5.4.5 Climate and Weather Update (Dionne)

CAC's Climate and Weather Update, a summary of current U.S. weather conditions has received favorable interest within NOAA. As a result, it has been requested that CAC increase the distribution of this product. Featured highlights in 1990 have included significant rainfall events in the Southwest and Midwest, as well as dryness in the Southeast and far West.

5.4.6 PRESTO - National Capital Summary (Miskus)

The publication quality of PRESTO (Precipitation Summary and Temperature Observations) has been improved and the production time has been reduced with the use of desktop publishing software. PRESTO, a summary for 5 stations in and around Wasington, D.C., is now completely produced using Apollo software, including the front page (figure 29). Color enhancements, however, are still done manually until color upgrade software can be obtained. Historic weather data for all the stations used in PRESTO are being transferred to a personal computer, which will enable easy access and statistical manipulation. The number of users that receive PRESTO has increased to 220, including 30 members of Congress. In addition, PRESTO is now incorporated into NOAA's monthly Metropolitan Washington Climate Review.

5.5 Supporting Projects

5.5.1 Communications and Graphics Applications (Laver)

The transfer of Versatec and Tektronix generation products has begun, with the installation of electronic plotters and the insertion of NCAR products on the Apollo network. Subroutines that create replications of Versatec products have been produced operationally at the World Weather Building and at JAWF. Also, a new interactive method produces analyzed temperature, departure from normal temperature, precipitation, and percent of normal precipitation maps for the Sahel region of Africa.

In addition, work is nearing completion to operationally transfer (from the Tektronix to the Apollo) average temperature and departure-from-normal temperature charts for the U.S. This chart (see figure 30) is currently published in both the Weekly Weather and Crop Bulletin and Weekly Climate Bulletin. All of the above activities have demonstrated the ability of the new-generation equipment to perform advanced automatic analysis techniques, to provide the flexibility to adjust maps subjectively and interactively, and to produce publication-quality output.

PRESTO

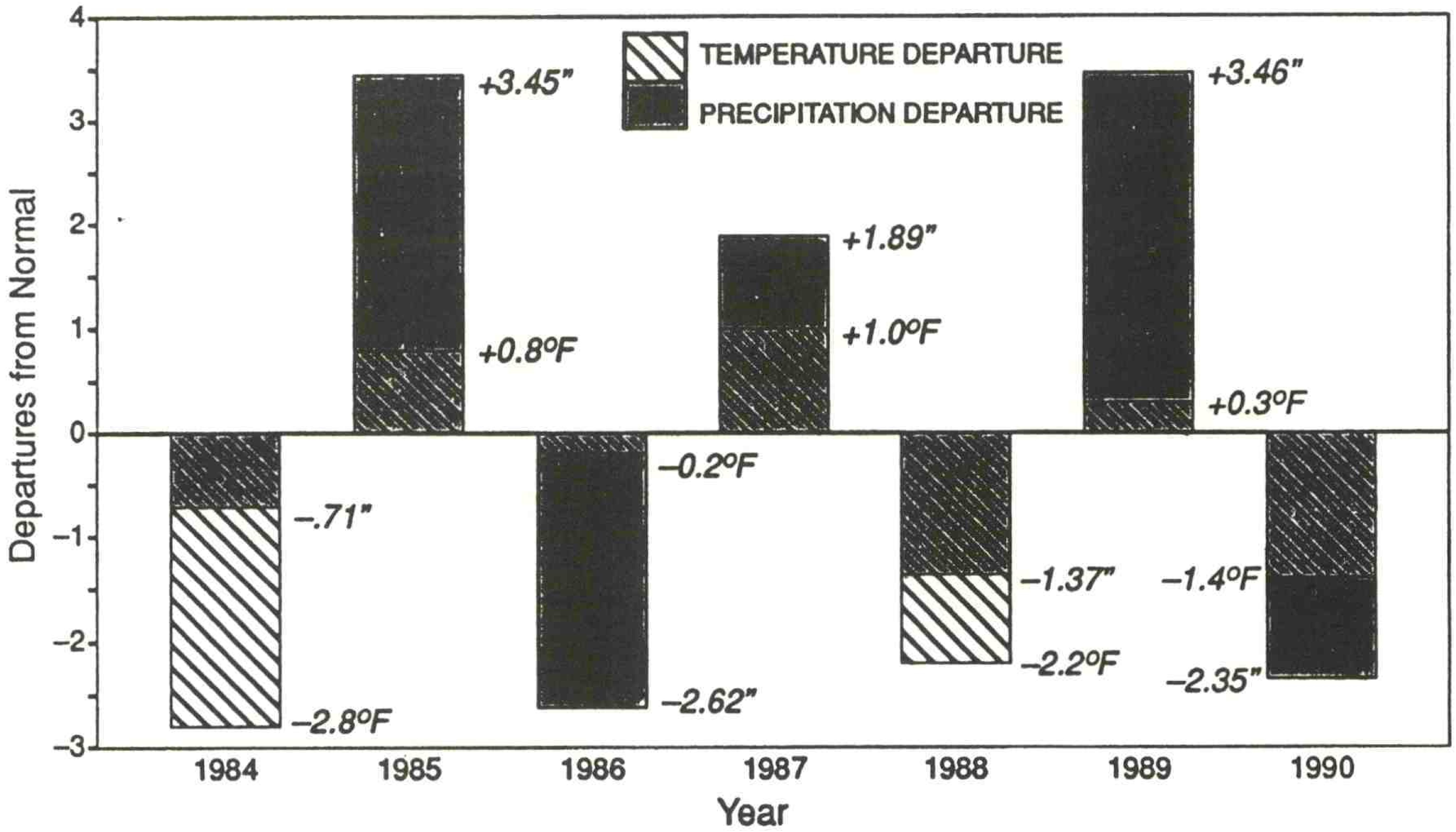
PRECIPITATION SUMMARY AND TEMPERATURE OBSERVATIONS
FOR THE WASHINGTON, DC & BALTIMORE, MD AREA

SEPTEMBER 1990

SEPTEMBER COINCIDENCE CONTINUES...EVEN–NUMBERED YEARS (E.G. 1990) BELOW NORMAL.

Since 1984, DCA has observed DRIER AND COLDER than usual Septembers during EVEN–numbered years and WETTER AND WARMER than normal Septembers during ODD–numbered years

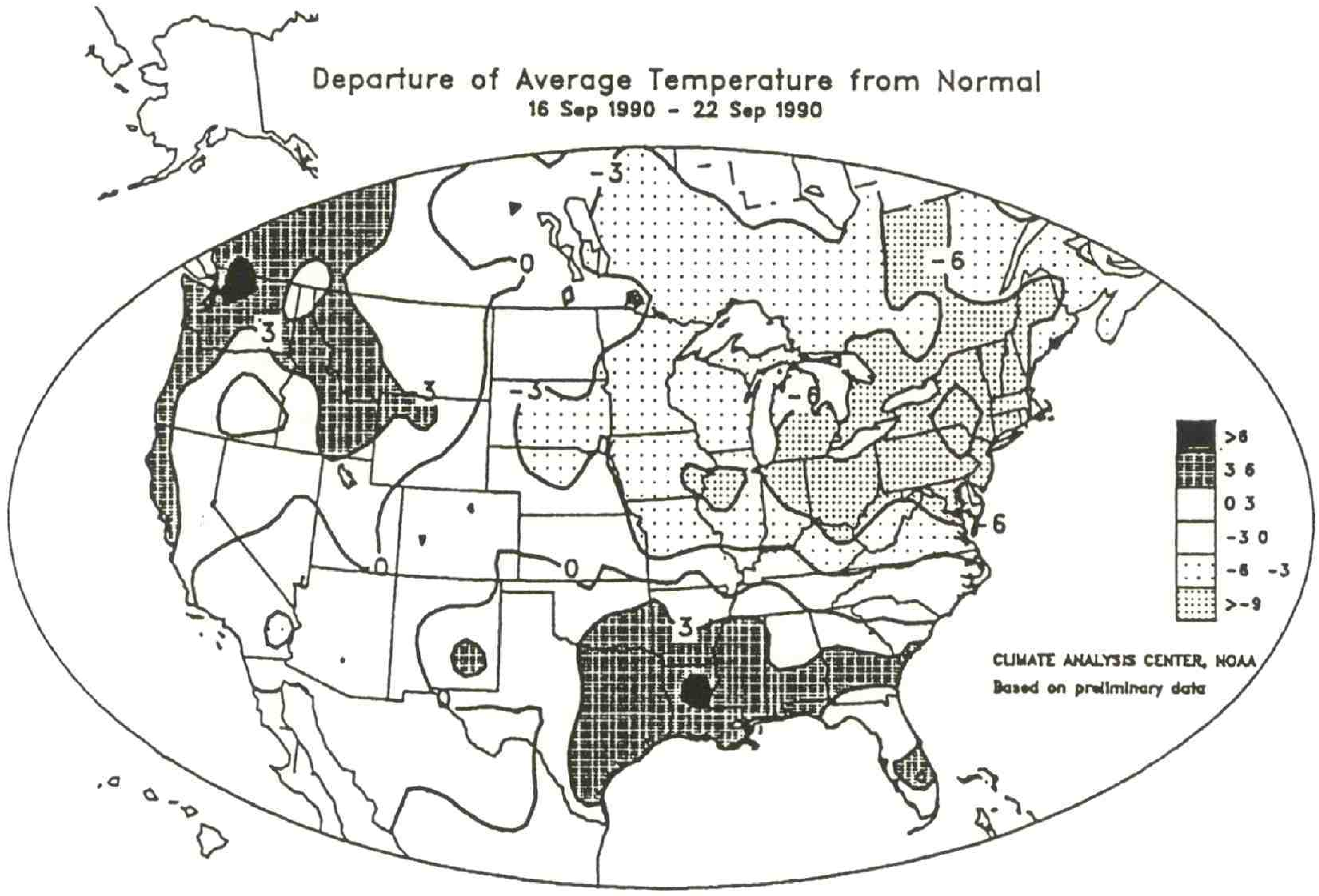
SEPTEMBER DEPARTURES FROM NORMAL
WASHINGTON/NATIONAL AIRPORT (DCA).



SEPTEMBER HIGHLIGHTS:

- *Least amount of precipitation at DCA in any month since 0.60" fell during September 1986;*
- *Driest September EVER at Andrews AFB (0.54") since records began in 1943;*
- *First successive precipitation–free weekends (Sep. 1–2, 8–9) at National since last year (Dec. 16–17, 23–24);*
- *First time since November–December 1989 that DCA observed consecutive cooler than normal months (August & September 1990).*

Figure 29 Front page of the September 1990 PRESTO [normally in color] that was produced by Apollo desktop publishing software.



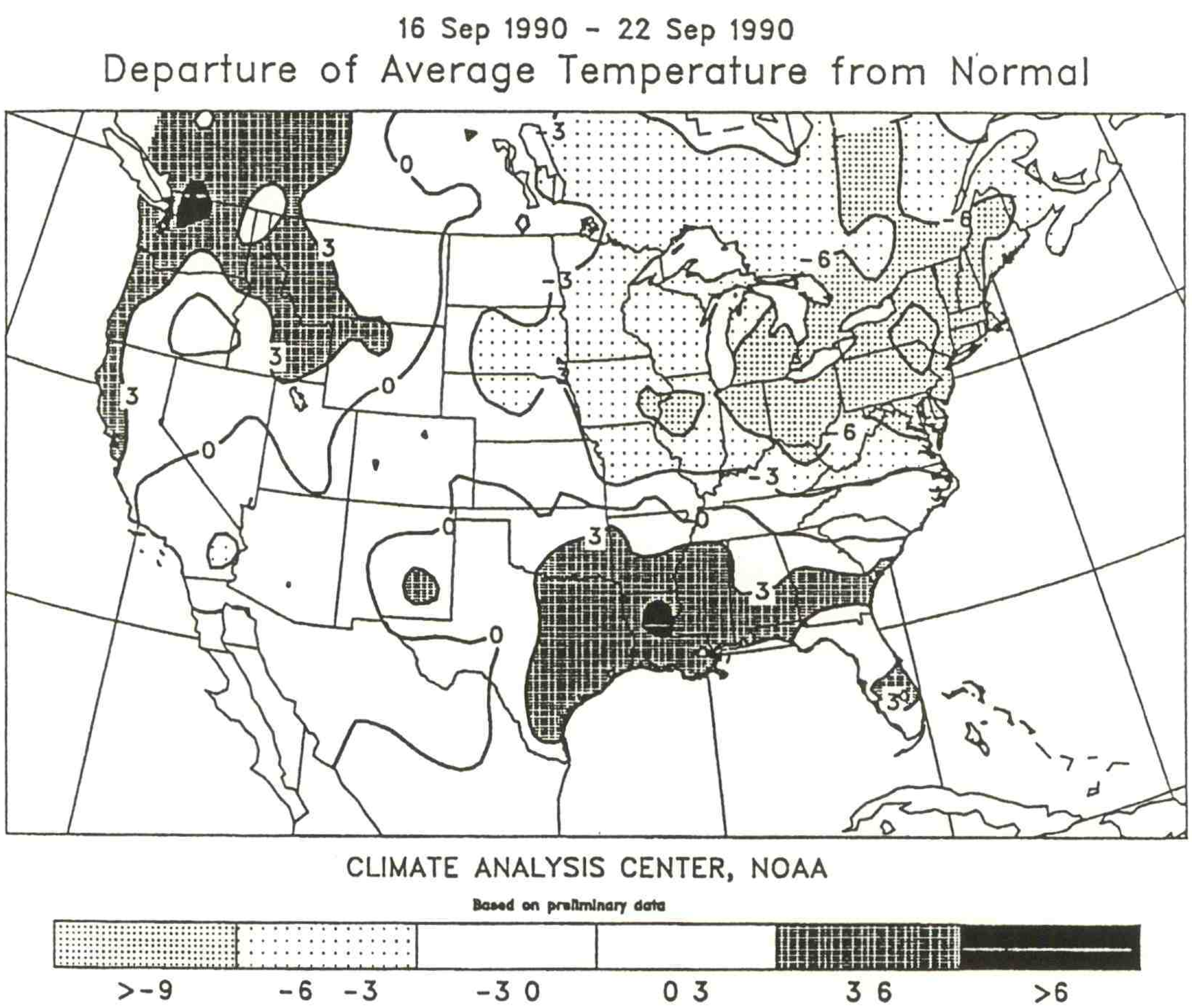


Figure 30 Examples of automated product generation on the Apollo system using modified NCAR graphics. Products are published in CAC's Weekly Weather and Crop Bulletin and Weekly Climate Bulletin.

A thin wire ethernet was installed at the Joint Agricultural Weather Facility (JAWF) at USDA. It links an APOLLO workstation, a PC, plotter, laser printer and a "router." The "router" connects JAWF to the WWB via a high-speed direct digital service line. This line is now operational and provides significant advancement in AIB/JAWF capabilities. Critical new aspects will include rapid data and graphics exchange, full screen edit on NOAA mainframes from JAWF, access to internet at JAWF, potential to network with other JAWF meteorologists and eliminate separate, outdated printer link to computer mainframes.

An ethernet line was also installed at the World Weather Building to link A&I Branch's computer workstations, printers and plotters. An ethernet "bridge" connects this sub-network to the main WWB ethernet and permits access to APOLLOs, mainframes, other devices on the network, as well as the outside world.

5.5.2 Satellite Monitoring Products (Laver, Tinker)

The reliability and quality of satellite images used in the African Sahel precipitation analyses has been improved by a new method of bringing METEOSAT imagery into the VDUC environment. Figure 31 shows approximately the form these images take, although color output enables the user to identify a greater number of count ranges than the gray scale. Programs were developed (by A. Herman, Ellsworth Associates) that demonstated the feasibility of inserting digital METEOSAT data (with precision geography) on the VDUC and then into the interactive Sahel analyzing program. After a 3-month test period, implementation of digital data will increase the number of daily images. At the same time, the precision geography will improve the accuracy of the Sahel analysis.

5.5.3 Climate Assessment Data Base (CADB) (Patterson)

Both the daily and monthly data files for the CADB are completely automated and error-free with regard to the downloading, storing, overwriting, and accessing of data. An archival system was developed and the data are now available both on magnetic tape and optical disk. Software was also developed to convert the daily summary data to the new format that enables users to access the daily data from 1978 to 1987 with the current version. In addition, the daily summary system was redesigned to permit data processing to continue with incomplete data and to prevent the daily database programs from running out of order. Finally, the CADB master station library was updated to flag North American locations with incomplete or missing precipitation reports.

5.5.4 JAWF Briefings (LeComte)

Meteorologists from CAC's Agricultural Weather Section briefed USDA crop analysts weekly on important weather events affecting global crop production. These briefings included: Fall 1989 dryness in the U.S. and north African winter wheat regions, mild winter weather in Europe, spring and summer dryness in western and southern Europe, and heavy spring and summer rains in the U.S. corn belt. Weather conditions were generally favorable for the world's major food-producing countries, with abundant rains benefiting summer crops in the Soviet Union, China, Canada, and the United States. Also, crops in southern Asia benefited from a good southwest monsoon season.

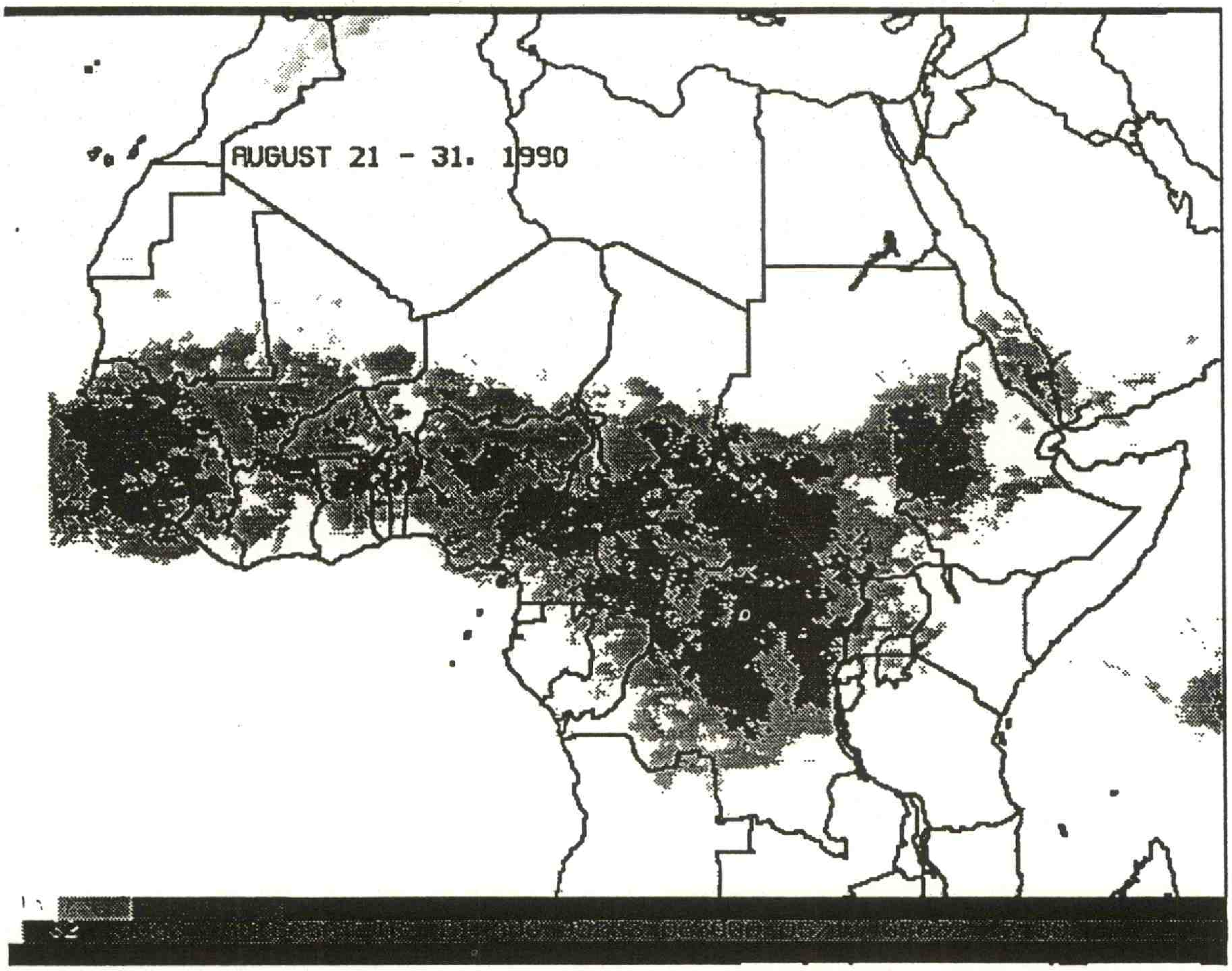


Figure 31 Accumulated cold cloud top counts across the African Sahel during August 21-31, 1990. Every three hours, a METEOSAT grid is incremented by 1 at all locations where the cloud top temperatures are below a critical value (i.e. where rain is likely occurring). Each gray shade represents a range of these occurrences (ranging from 0 [white] to >12 [black]) out of a possible 88. Normally, 16 shades of color are used rather than 4 shades of gray to allow for considerably more detail.

THIS PAGE INTENTIONALLY LEFT BLANK

6. CLIMATE PREDICTION

6.1 Empirical Studies

6.1.1 Medium Range (6-10 Day) Forecast Development (Epstein)

An "Imperfect Prog" system has been developed for statistically post-processing model output to produce MRF-based 6-10 day precipitation and temperature predictions. This system, which is still undergoing testing and refining, is less demanding than the Model Output Statistics (MOS) system and explicitly deals with the decreasing predictability of potential and selected predictors (actually specifiers) in the Perfect Prog system of statistical forecasting. Predictions of precipitation are given in terms of the probability of measurable precipitation occurring on 0, 1, or 2 or more days of the 6-10 day period. Predictions of temperature are made directly in terms of standardized anomalies from the climatological normal 5-day mean temperature, but will be expressed as a range of temperature in which the 5-day mean will fall with some specific probability (say 80% or 90%).

Although this method still requires more testing and tuning, it is clear that the temperature predictions are much more skillful than the precipitation predictions. In the developmental data sets the variance explained of the 6-10 day mean temperature, even accounting for the loss of predictability of the selected predictors, was mostly between 60 and 70%. As per the example in figure 32, the amount of variance reduction is strongly influenced by the fields from which the predictors can be chosen. The comparable value for the reduction of variance of precipitation, using an earlier and more primitive set of predictability factors and predictors, is near 10%.

In addition to the above efforts, some advances have been made in the use of harmonic smoothing to represent the annual cycle. Results from one study show a simple but consistent objective way of representing daily climatological normals when the given input are monthly means. In another study, a method was found for determining the optimum number of harmonics to use to describe an annual cycle without either underfitting or overfitting the observed data.

6.1.2 Seasonal Empirical Prediction (Livezey, Barnston)

A QBO phase-conditional relationship between the 11-year solar flux and the U.S. surface temperature in mid-winter through early spring failed in 1989 during the cold ENSO episode. Subsequent research indicated that the state of the ENSO as well as the solar/QBO situation do indeed affect the climate, and that the two factors may offset or enhance one another depending on their values and on location. Since then, a QBO phase-conditional relationship between the 11-year solar flux cycle and U.S. surface temperatures and Northern Hemisphere 700 mb heights held up for mid-winter 1990. These findings and other relationships are described in a paper that was submitted for publication (Journal of Climate). The manuscript has been revised into two separate papers, with the second article emphasizing the connection between extratropical wintertime climate, ENSO and the QBO.

EXAMPLES OF THE FREQUENCY OF SELECTION OF PREDICTORS

POTENTIAL PREDICTOR		ORDER OF SELECTION				AVERAGE ESTIMATED EXPLAINED VARIANCE
field	offset	1	2	3	4	
H_{850}	0	0	31	21	27	
H_{500}	0	28	6	16	8	
H_{850}	2	4	5	9	6	44.3%
H_{500}	2	16	6	2	7	
H_{700}	0	0	2	5	9	
H_{500}	0	0	7	0	3	
T_{850}	0	42	32	31	27	61.3%
T_{700}	0	6	7	12	9	

Figure 32 Examples of the frequency of selection and effectiveness of predictors for 5-day mean temperatures.

A study was completed on the feasibility to stratify cold season height-lag correlations, dependent on whether a warm or a cold ENSO event, or neither, is taking place. Correlation fields and their statistical significances are being generated for operations. An example of the statistical significance field of one-season 700 mb height-lag correlations over North America is shown for all years [figure 33 (a)], and for only those years when warm or cold ENSO events were in progress [figure 33 (b)].

6.1.3 Prediction and Specification Studies (van den Dool)

In a follow-up to a recently completed study that described 12-hour height forecasts through limited area analogs, numerical experiments are being conducted. The purpose is to further understand the workings of antilogs, and the non-linearity of atmospheric flow. New findings show that for a period up to 12 hours ahead, the tendency in geopotential is primarily determined by the linear terms in the voticity advection. Therefore, mirror images (antilogs) can be used to study nature's degree of linearity. In an extension of a related study on mirror images of atmospheric flow, a "bogus" analog was constructed using a linear combination of cases. This idea is being tested on the U.S. Climate Division data set (1931 - present), which will employ both monthly temperature and precipitation to define an analog.

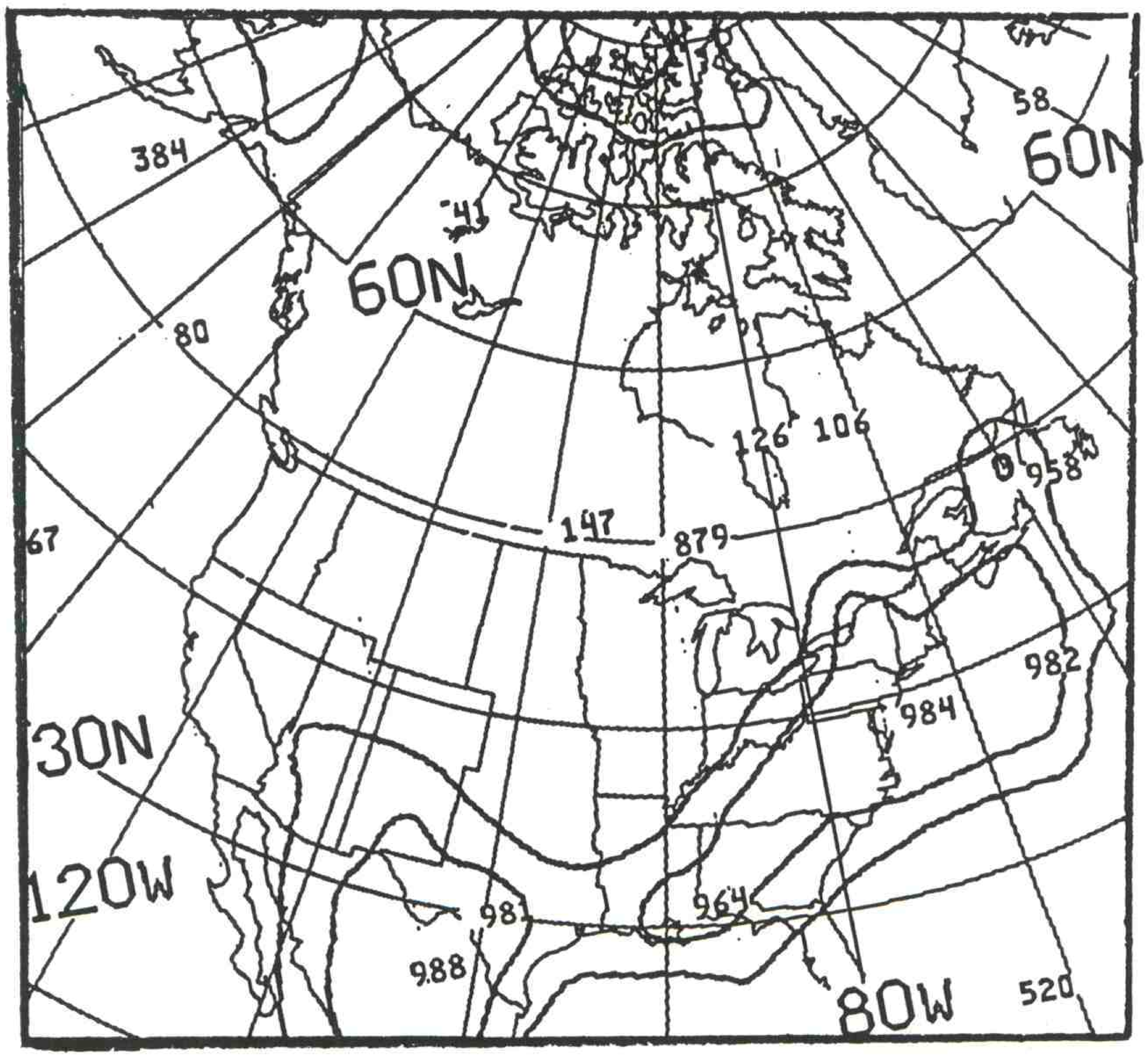
In a joint study (with Z. Toth, Hungary), the lack of success in forecasts for near-normal weather has been investigated. Results have revealed an explanation of this strange phenomenon. For categorical forecasts (using the Heidke skill), the reason for low skill near the mean is that while forecast methods have approximately uniform RMS errors, the class width is narrowest near the center. It was also discovered that for similar reasons the anomaly correlation increases linearly with the anomaly magnitude, when the magnitude is small. A paper, describing these results, is being submitted for publication (Weather and Forecasting).

6.2 Dynamical Methods

6.2.1. DERF - Operational Feasibility Assessment (Tracton, Ebisuzaki)

A subset of cases of the DERF III experiment (Lagged-Average Forecast versus Monte Carlo ensembles) was rerun with the higher resolution version of the MRF model. In addition to the random perturbation approach, a scheme was developed for generating Monte Carlo perturbations based upon differences between forecasts from NMC, ECMWF, and the UK Met Office. The goal is to develop the optimum strategies for expressing forecast uncertainties, based upon the divergence of predictions within ensembles. The results, separately or in combination with relationships between predictability and regime (see 6.2.2 below), are aimed at developing a capability for predicting forecast skill. Experiments, to date, suggest that the details of constructing ensembles are not relevant if the cloud model solutions, as true more often with the low-resolution model, does not include a result close to reality. Additional tests with the higher resolution model are in progress.

A



B

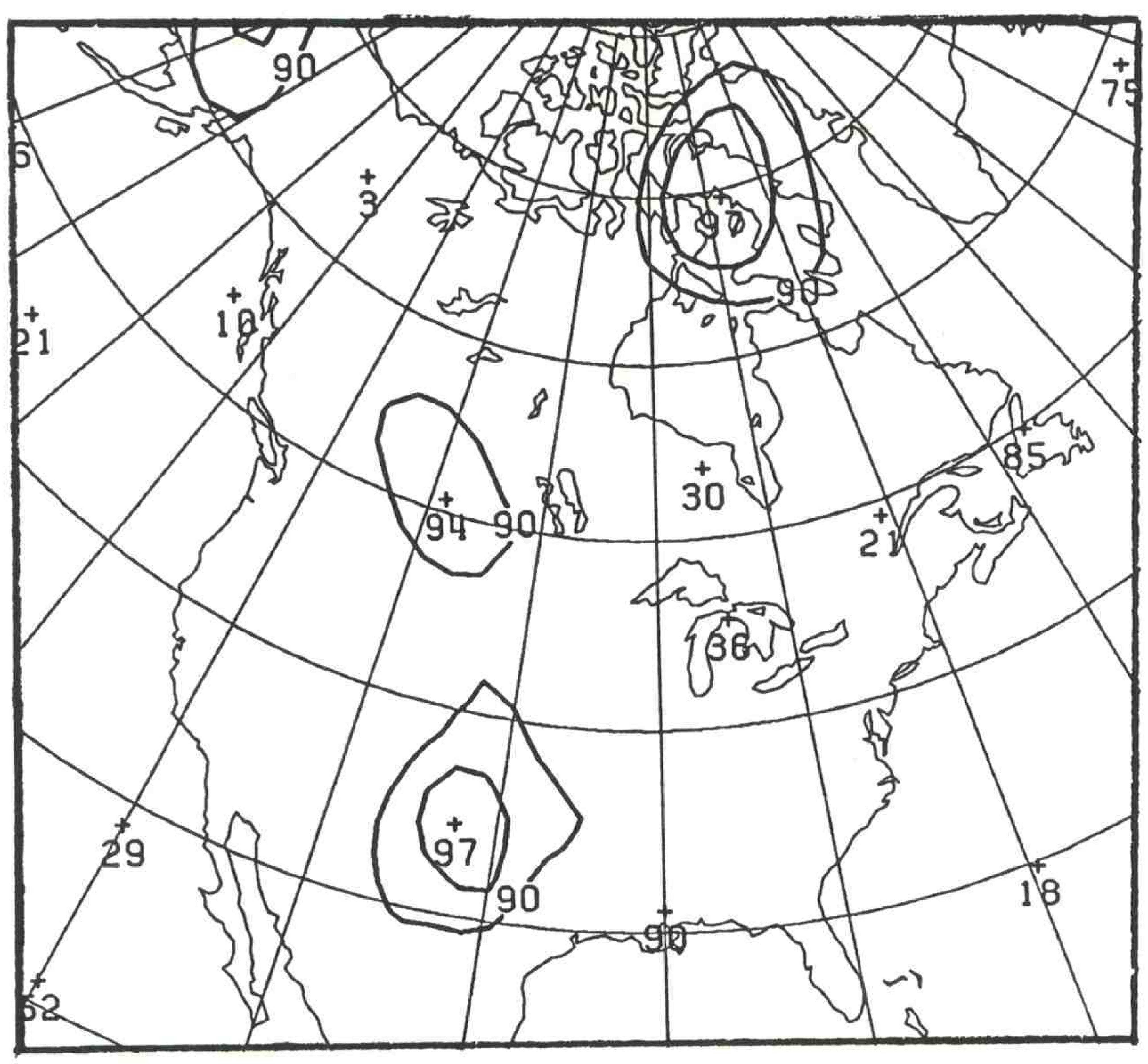


Figure 33 The field of statistical significance of point-wise one-season lag correlations over North America for fall 700 mb heights leading winter heights, for (part a) all years, and (part b) only years during which warm or cold ENSO events were in progress. The 90% and 95% statistical significance levels are contoured.

6.2.2 DERF - Regime Dependent Predictability (Tracton)

This study is focused on assessing relationships between predictability and circulation regimes. A number of tools and procedures for identifying regimes and regime transitions (e.g., teleconnection indices, measures of blocking activity, and diagnostics of scale interactions) have been developed and applied to DERF and operational MRF data sets. One of the most pronounced relationships to emerge is the one between blocking and skill. Detailed diagnoses have established that a key element in predicting blocks is sufficient resolution to resolve the interactions between planetary and sub-planetary scales. This work has been extended to investigate the role of scale interaction processes in regime transitions.

A comprehensive search was conducted to identify about 30 cases that will be used in additional DERF experiments related to regime predictability. This effort, in coordination with NCAR and ECMWF, follows recommendations of a recent DERF Workshop (held in Boulder, CO, June 1990). The goal is to provide further understanding and insights necessary for progress in numerical long-range prediction. Forecasts are now being generated for selected cases.

6.2.3 DERF II Spinoff Test (Tracton)

This experimental study, based upon the results of DERF II, was designed to explore the practical gains possible from the potential predictability beyond the medium-range. It involved comparisons between operational and "revised" Monthly Outlooks of surface temperature anomalies over the United States. (The revised forecasts were produced immediately after release of the operational Outlook.) These forecasts were based on extensions of the MRF to 15 days and measures of confidence in the extensions derived from a lagged- average forecast (LAF) ensemble spread. The test run began in December 1988 and continued at a rate of two cases per month through April 1990. Details of the experimental design and results have been documented in an internal CAC manuscript. The main finding shows that there is no significant gain in skill through the use of the MRF extensions. The problem apparently is due to the limited number of members (5) in the LAF ensembles and relative coarseness in their spacing (24 hours). With the recent acquisition of the CRAY computer by NMC, an experiment will be implemented that will include 9-member ensembles and 6-hour spacing.

6.2.4 MRF Model Skill Prediction (Chen)

Based on the MRF model, analyses were performed on DERF III experimental data that relate to both Monte Carlo and Lagged Average Forecasts. Preliminary results show that the skills of the Monte Carlo ensemble forecasts are not generally better than those of the deterministic forecasts. It was also found that the spread among the members of the ensemble is not well correlated to the skill of the forecast. It appears that the perturbations to the initial conditions were too arbitrary and should probably be generated in the regions of maximum dynamic instability. This is where the analysis is most sensitive to the uncertainties of the initial conditions.

6.2.5 MRF Model Behavior and Predictability (Chen)

An evaluation was made, using the NMC/MRF model, to assess the impact of transient eddies on the establishment and demise of a blocking flow. An experiment was run for 6-10 day time mean forecasts of 500 mb geopotential height anomalies. Figure 34 shows the verification run (panel a) and control run results (panel c) of this experiment. The figure also shows (panel b) that when the fast propagating small-scale disturbances are suppressed from the initial conditions, the subsequent forecasts fail in the prediction of block establishment. It can also be noted (panel d) that if the transient eddies are enhanced in the initial conditions to compensate for the subsequent deficiency of the model, blocking flows are well predicted.

6.2.6 Prediction of MRF Forecast Errors (O'Lenic)

A technique to find and remove systematic errors in MRF forecasts, elicited by the presence of low-frequency modes in the model initial conditions, is being evaluated in the 6-10 day operation. Since the MRF has changed greatly since 1982, an investigation is underway to determine the minimum number of prior forecast error fields needed to formulate the systematic error composites.

6.2.7 Simplified Dynamical Models (van den Dool)

In a joint study (Cai, University of Maryland and J. Feng, visiting scientist, PRC), teleconnections were calculated dynamically based on a one-layer model similar to a Barotropic Vorticity Equation (BVE) Model. Essentially a height anomaly is imposed in a certain geographical area and the response is calculated elsewhere. This is similar to the process followed in seasonal and monthly forecasting where a forecaster is confident about the height anomaly in some area(s) and tries to fill in gaps through statistical teleconnections. The BVE-model has a wavy basic state, and a scheme was employed to turn non-linearity on or off. This will suppress (enhance) the divergent part of the basic state's flow and can be used for short-term integrations and to find steady states that may be relevant to long-range forecasting. The primary purpose of seeking steady atmospheric states is to investigate what happens to monthly mean anomalies when the annual cycle in the basic state evolves while everything else stays the same. This was done for the month of August for 10 years (1979-1988). Preliminary results indicate that changing the basic state had a beneficial impact on forecasting anomalies for the month of September.

In another joint study (with Cai, University of Maryland), a symbiotic relationship was found between low-frequency waves and traveling storm tracks. Figure 35 shows storm tracks that travel along with the low frequency wave. It can also be seen that the high frequencies reinforce the low frequencies; that is, they cause deepening where a trough already exists. A paper, describing these results, has been written and submitted for publication (Journal of Atmospheric Sciences).

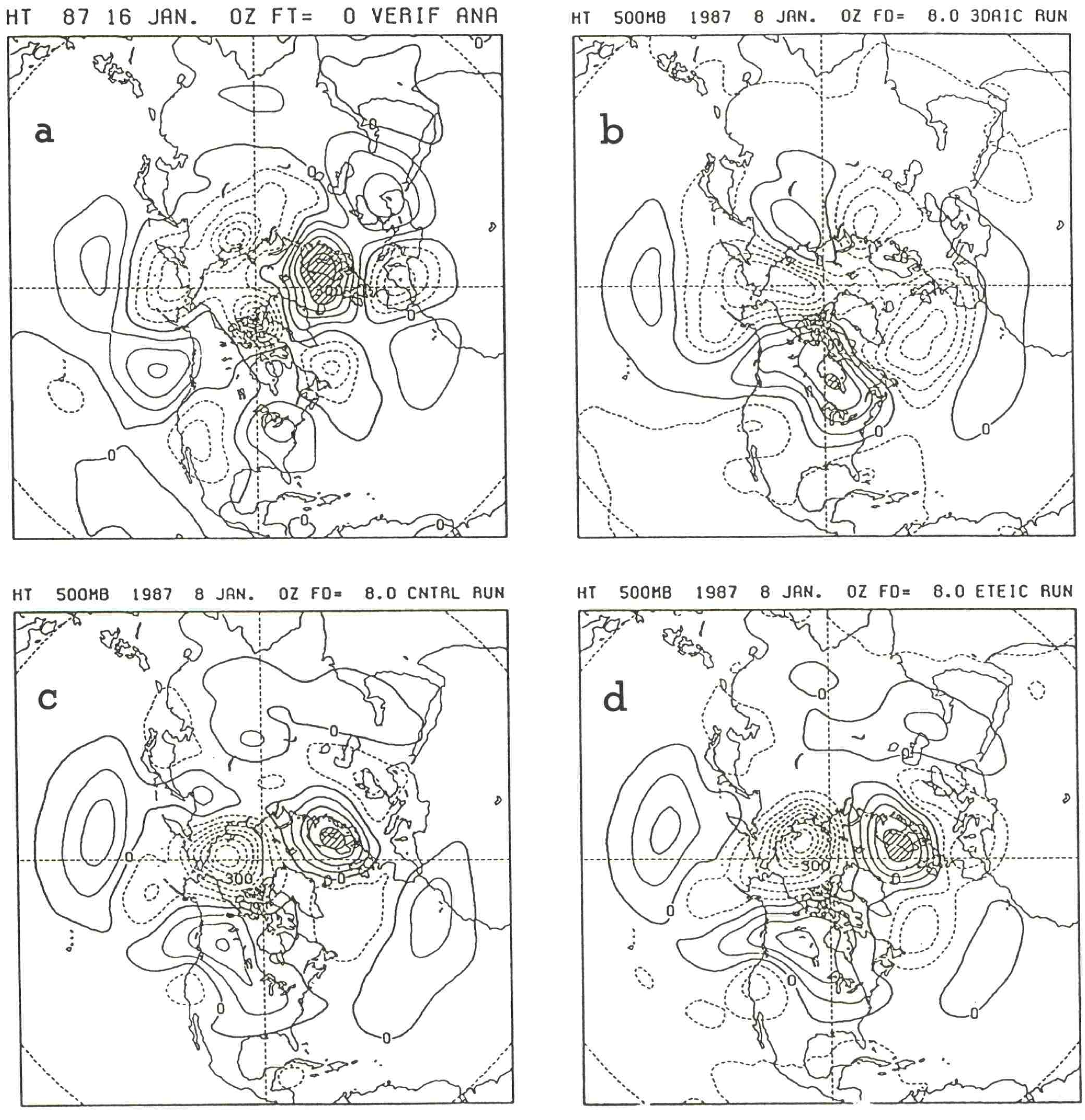


Figure 34 Six to ten day (D+8) time-mean forecasts of 500 mb geopotential height anomalies initiated on January 8, 1987: (a) verifying analysis, (b) decreased initial condition run, (c) control initial condition run, and (d) enhanced initial run. Positive anomalies are shown by solid curves, negative anomalies by dashed curves. Contour interval is 60 meters, the shaded areas represent positive anomalies greater than 240 meters.

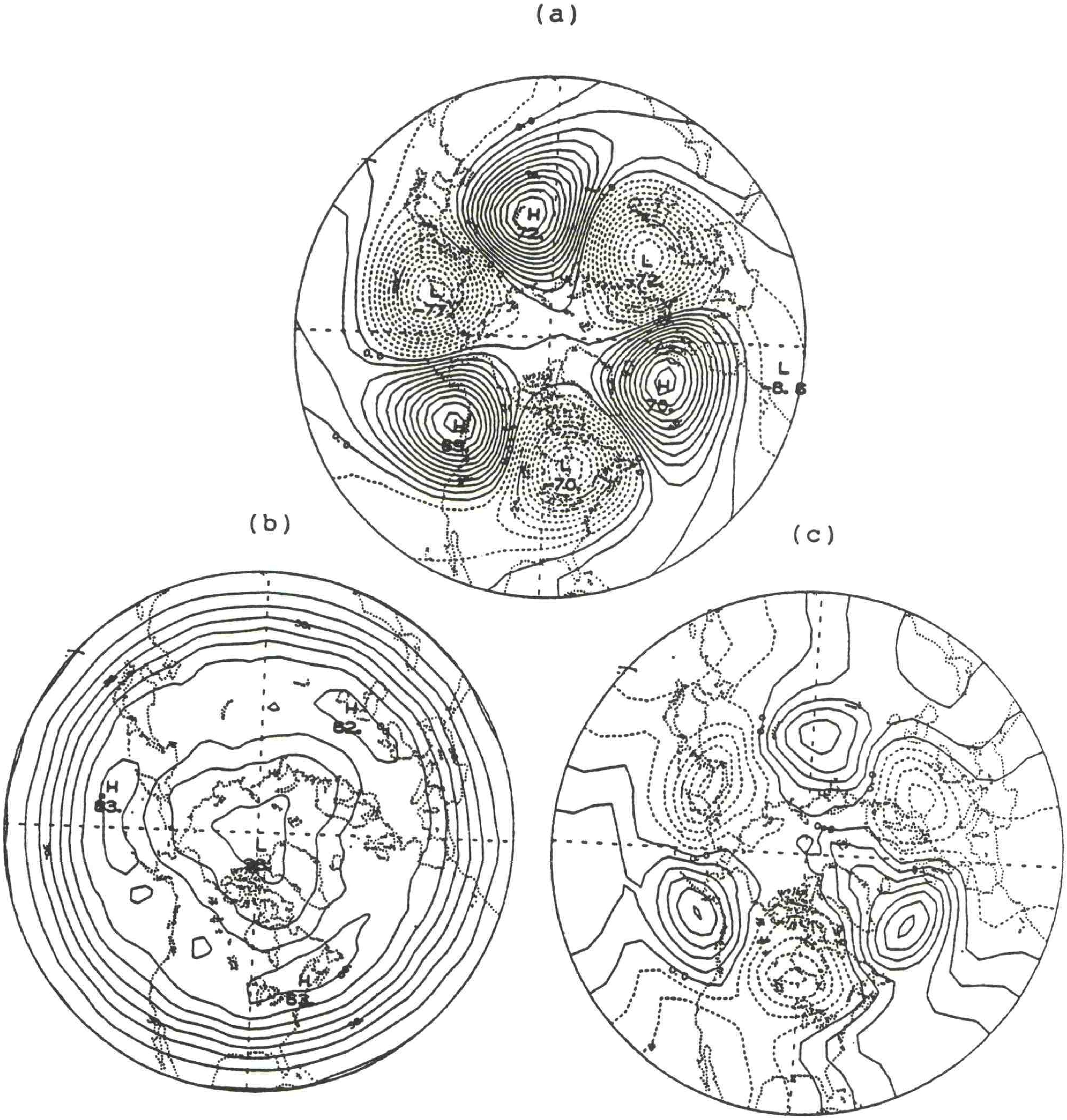


Figure 35 The time-mean low frequency field (derived from daily 500-mb height anomaly fields for 10 winters) is given in (a), the rms of the high frequency height field in (b) and the feedback (i.e., height tendency) of high onto low frequencies in (c). The trough in zonal wave number 3 was identified at $50^{O}N$ in the low frequency height field on each day. The maps were rotated to a reference longitude (arbitrary), the low as well as the high frequency field.

6.3 Evaluation

6.3.1 Evaluation of Operational Outlooks (Livezey)

The modernization, automation and expansion of the Prediction Branch forecast verification system is underway. The existing monthly and seasonal system had to be reconstructed and forecasts are now again routinely verified in real time, but more efficiently. This improvement is due to both automatic and interactive digitization of observations and official control forecasts. Software was then adapted to an Apollo computer, streamlined, and made more flexible. These actions are enabling the expansion of the surface forecast verification system and the development of an upper-air verification system.

In regard to surface verification, developed software now enables the generation of time-series of forecast skill, long-period contingency tables, and maps of skill in the contiguous United States. This information will eventually form the basis for management summaries, and after appropriate research, substantial new forecaster and user guidance. The work is motivated by the arguments presented in a recently published paper (Livezey, BAMS, March 1990) that describes the variability of long-range forecasts and implications for their use and value. In regard to the upper-air verification system, planning was completed and a skill assessment method that employs a decomposition of forecast skill has been designed and tested. The stage is now set for application to studies of upper-air forecast skill variability.

6.4 Operational Products

6.4.1 Six-to-Ten Day Forecasts (Hughes)

Verification of CAC's operational 6-10 day temperature and precipitation forecast shows the following results. It appears that the temperature skill scores for both the 3 and 5 class will set records for 1990. So far, 4 monthly record scores have been set. The 3-class precipitation skill score, however, will probably not set a record for 1990. Instead, it is on the same level as the scores of recent years. From January through September 1990, only 2 monthly records have been set. The standardized correlation score for CAC's official D+8 500-mb height prog for North America is also on the way to a record for 1990. Figure 36 shows correlation scores for the CAC official prog, the NMC/MRF model, and the ECMWF model.

6.4.2 Monthly Outlook (O'Lenic)

The skill of CAC's monthly U. S. temperature forecasts, as measured by the Heidke skill score, was above the 1981-1988 average within each season, except winter, as shown by figure 37. This figure depicts the seasonally-averaged skill scores of monthly temperature predictions. One of the most challenging forecast situations faced by Prediction Branch forecasters was the preparation of U.S. temperature forecasts for December 1989 and Winter 1989-90. While, the <u>monthly</u> forecast called for cold in the east, the <u>seasonal</u> forecast called for warmth in that region. As it turned out, the eastern U.S. experienced one of the coldest Decembers on record (see figure 38), while the mean temperature for winter ended up above normal in that region.

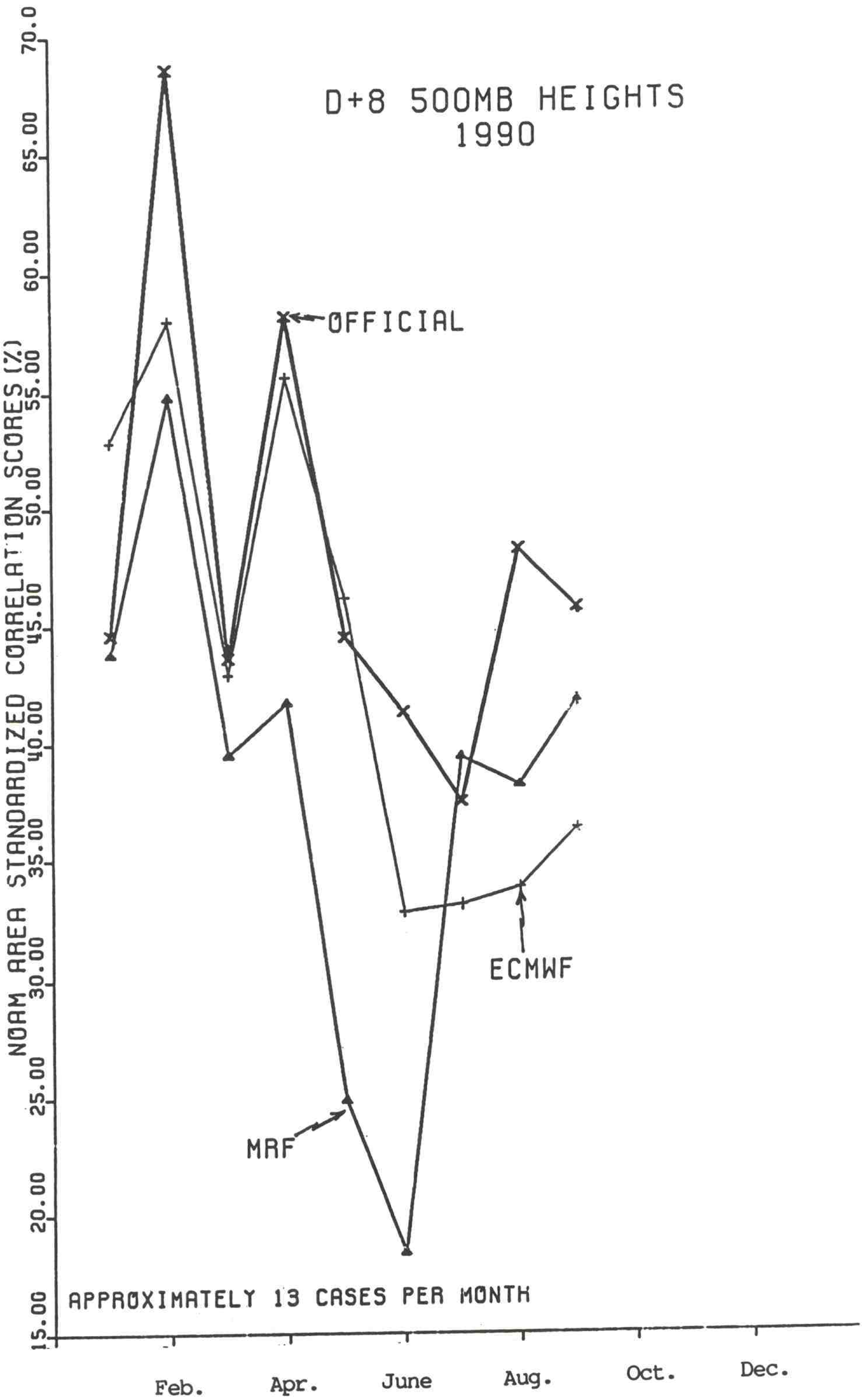


Figure 36 Monthly standardized correlation scores (%) of the D+8 500-mb height progs for North America in 1990. The 3 curves are for the NMC/Medium Range Forecast (MRF) model, the European Center (ECMWF) model, and CAC's Official prog. The latter is a blended product that combines the ECMWF prog, a bias-corrected MRF prog, a linear-regression prog, and analogs.

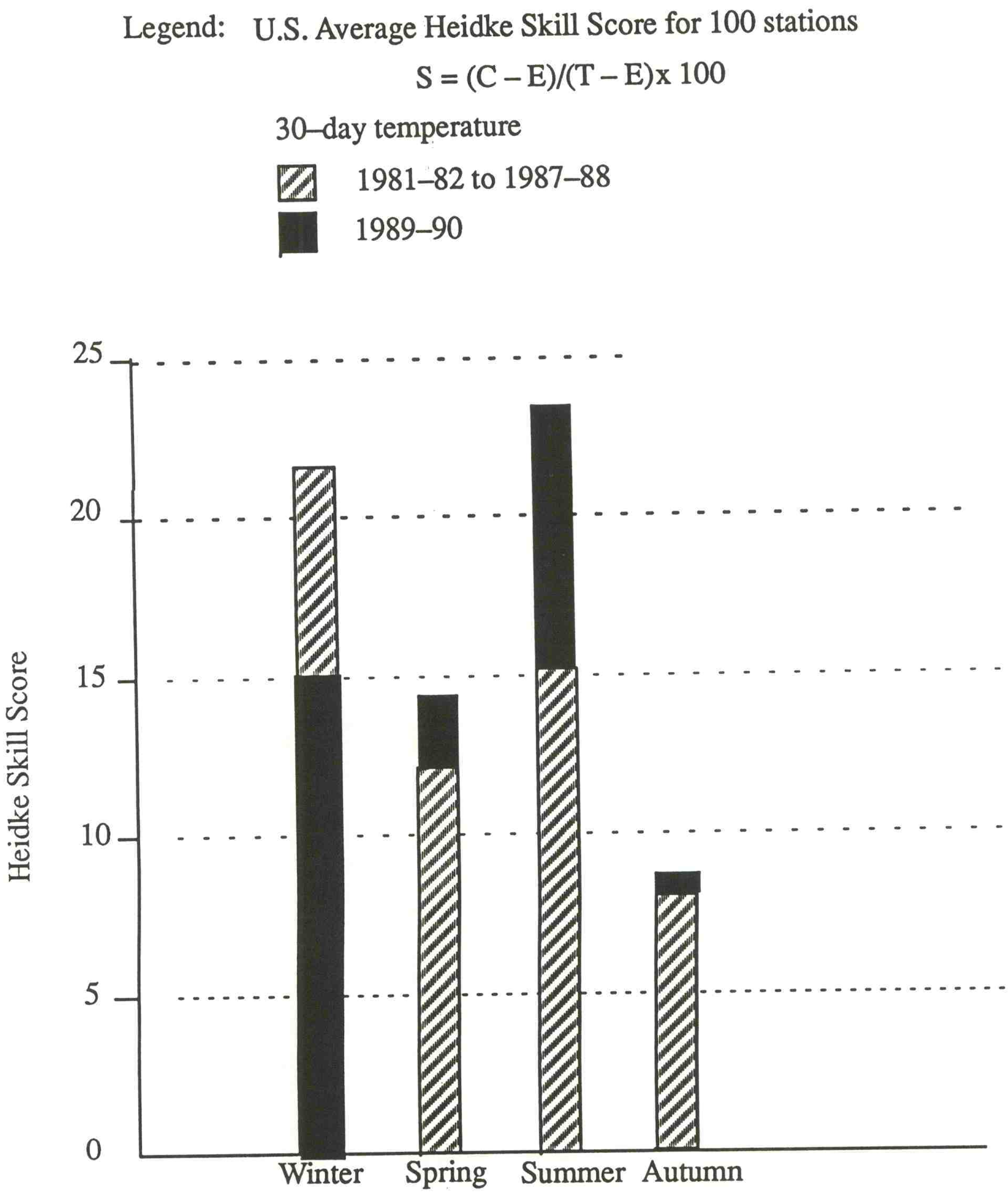
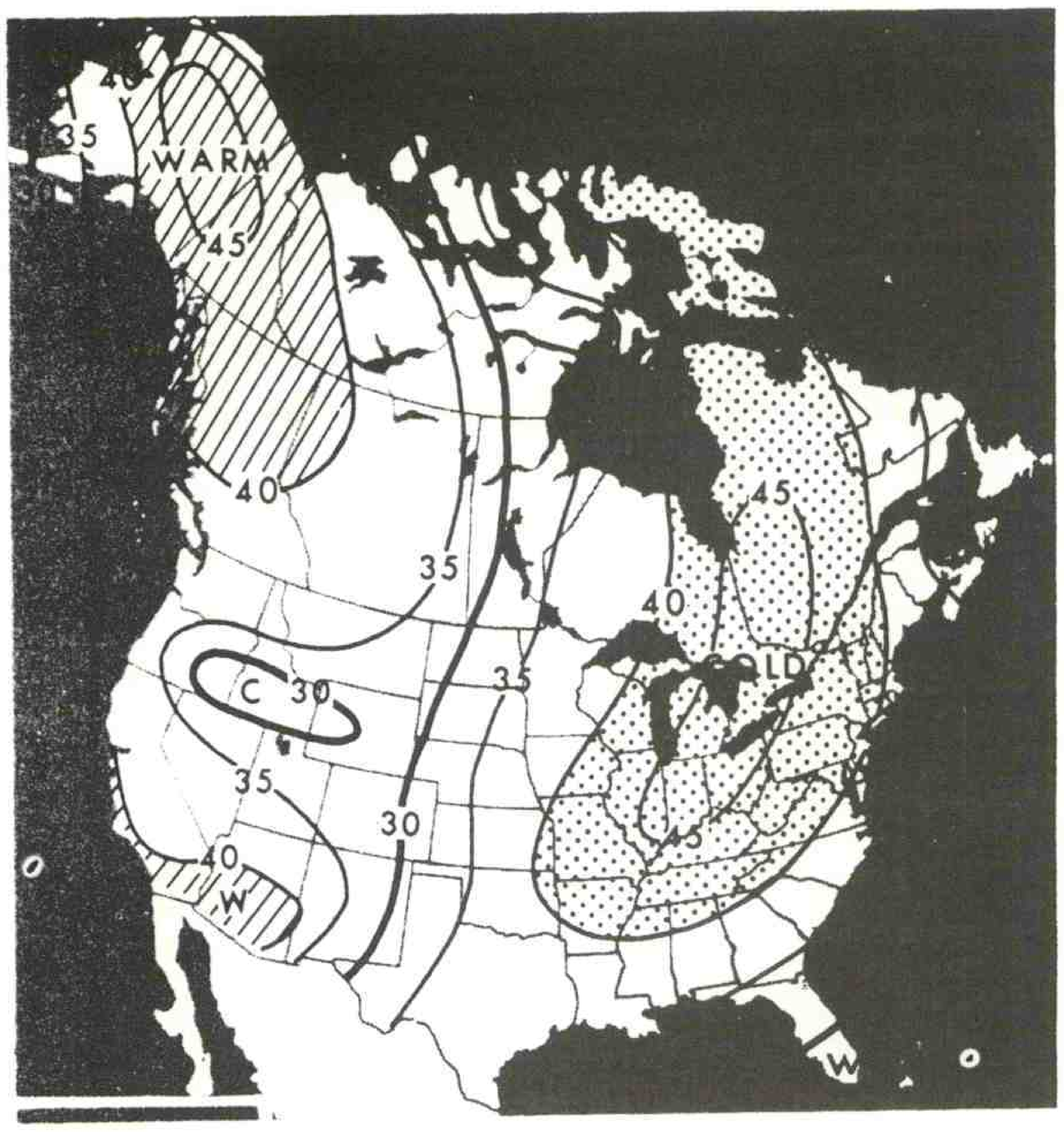
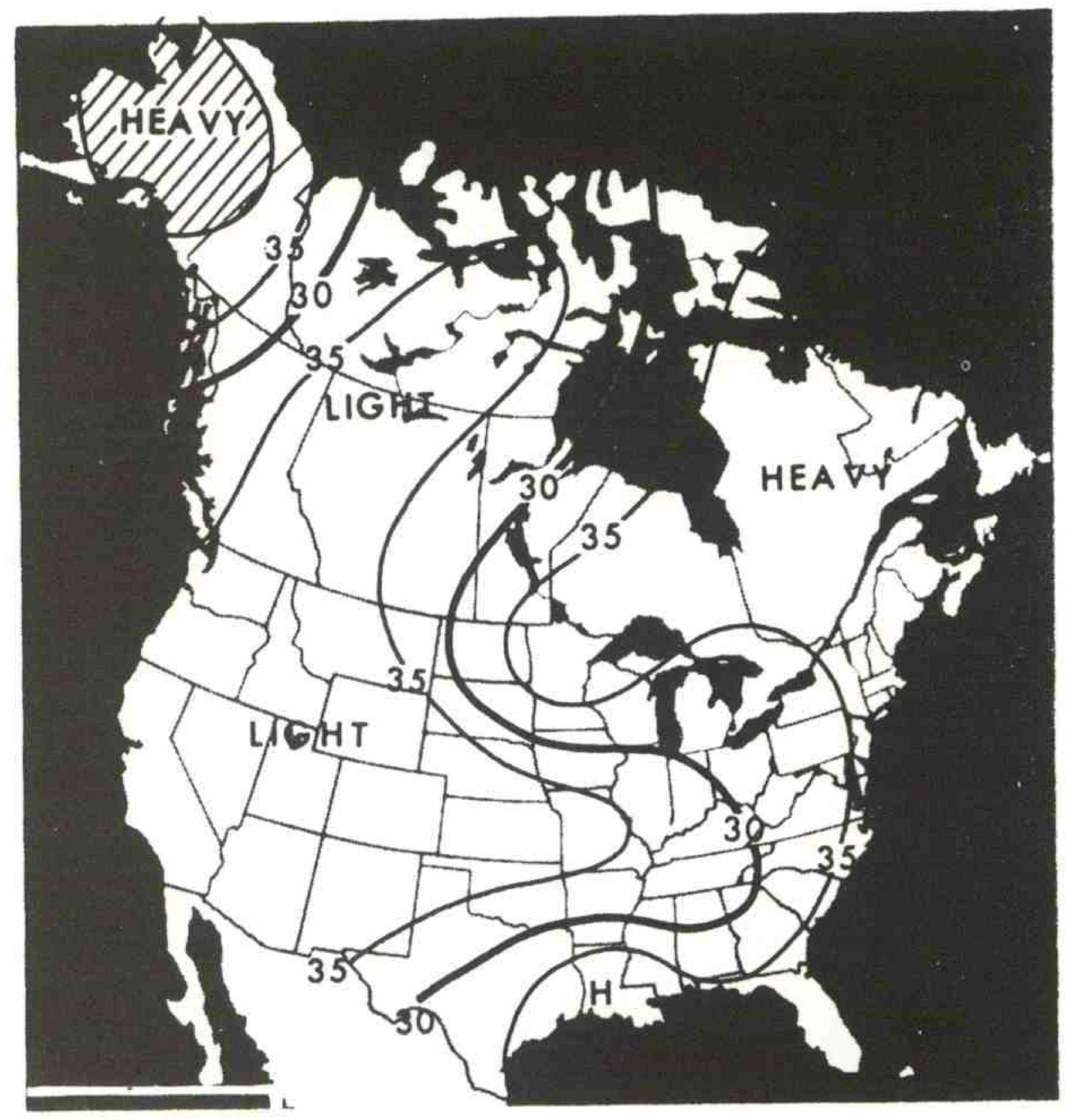


Figure 37 Average Heidke skill score for 100 U. S. stations from CAC's monthly temperature forecasts. Bars show the average forecast skill for individual seasons, with 1981-82 to 1987-88 denoted by hashed lines and 1989-90 denoted by solid area.

FOR DECEMBER 1989

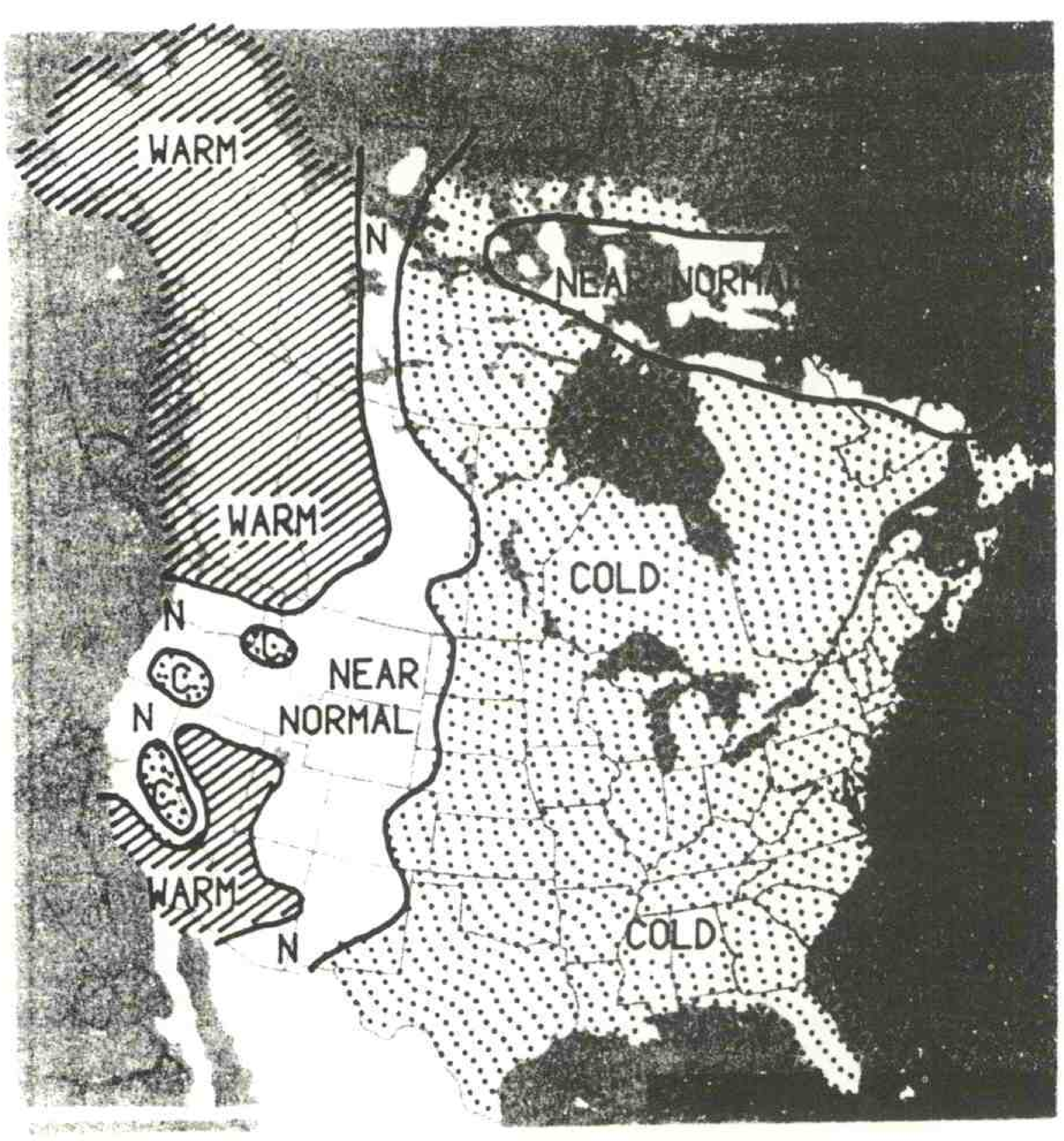


TEMPERATURE PROBABILITIES



PRECIPITATION PROBABILITIES

OBSERVED FOR DECEMBER 1989



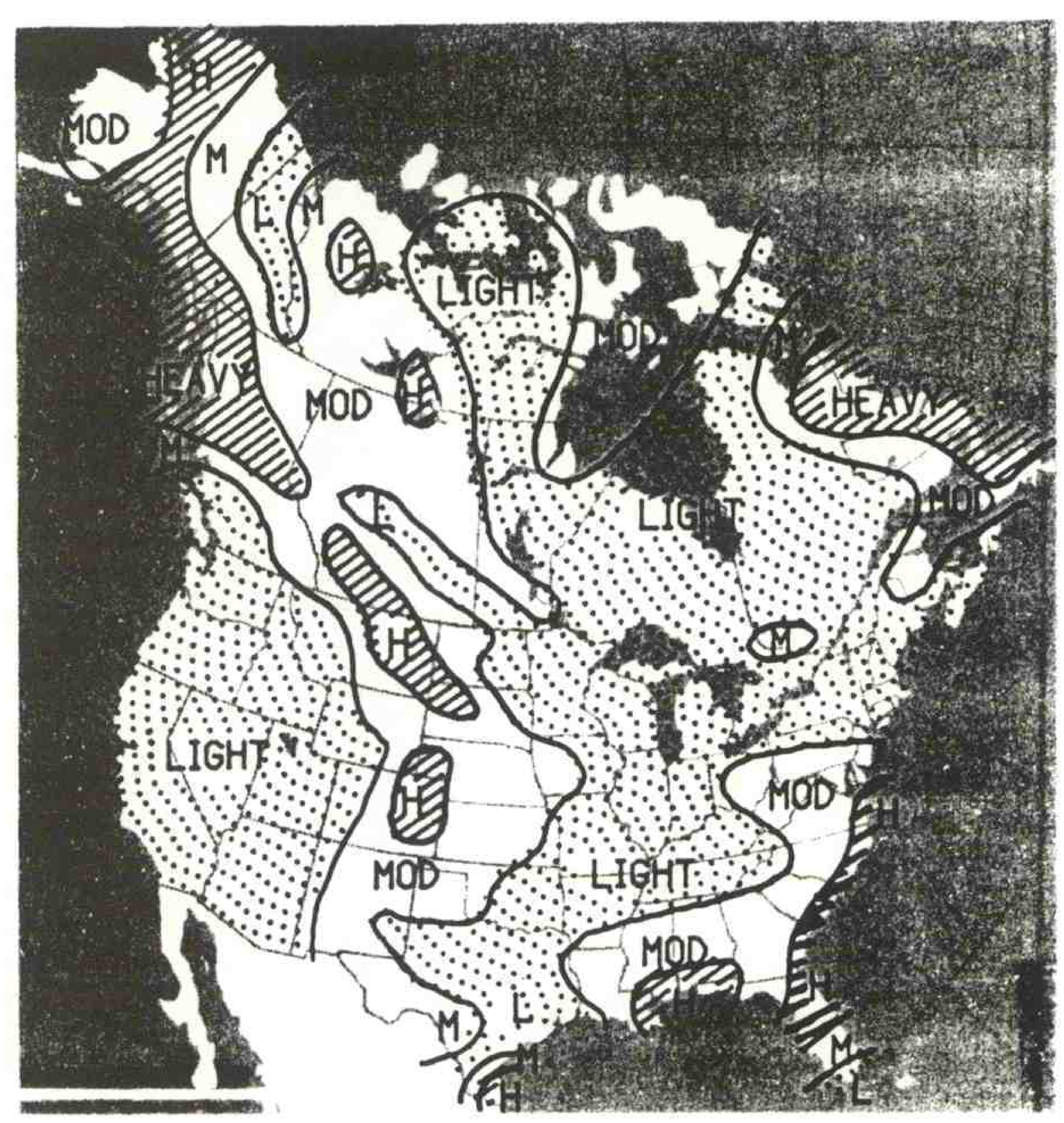


Figure 38 CAC's monthly temperature and precipitation probability forecast for December 1989 (top). Observed temperature and precipitation for December 1989 (bottom).

CAC's monthly U.S. temperature forecasts during the summer (again, see figure 37) were also successful. This result is due in part to useful guidance from both the MRF model and statistical tools and may indicate a period of greater than average real predictability.

6.4.3 Seasonal Outlook (O'Lenic)

CAC's winter 1989-90 temperature forecast for the eastern U.S. called for warmer than average conditions, and despite a record cold December, this is indeed what occurred (see figure 39). This guidance was presented before a group of government and private-sector energy decision makers at an emergency meeting convened at the U.S. Department of Energy. It was held on December 23, 1989--at the height of the cold outbreak in the eastern United States.

6.4.4 Modernization of Forecast Operations (O'Lenic)

A milestone was recorded in the modernization of CAC's forecast operations. CAC's published Monthly Outlook for mid-January to mid-February 1990 was the first to be produced using semi-automated procedures. Software, installed on an Apollo computer, now streamlines the operation of many 30-day products and some products required for the 90-day and 6-10 day operations. Menu-driven software permits codes to be invoked in a manner consistent with normal procedures established for the 30-day operation. Also, the use of color plots has proven to be a valuable tool in the conversion from manual to machine manipulation of maps. Plotting anomalies on a map in three different colors often makes the drawing of contours unnecessary. Efforts are continuing toward the goal of automating as many operational procedures as possible.

6.5 Supporting Projects

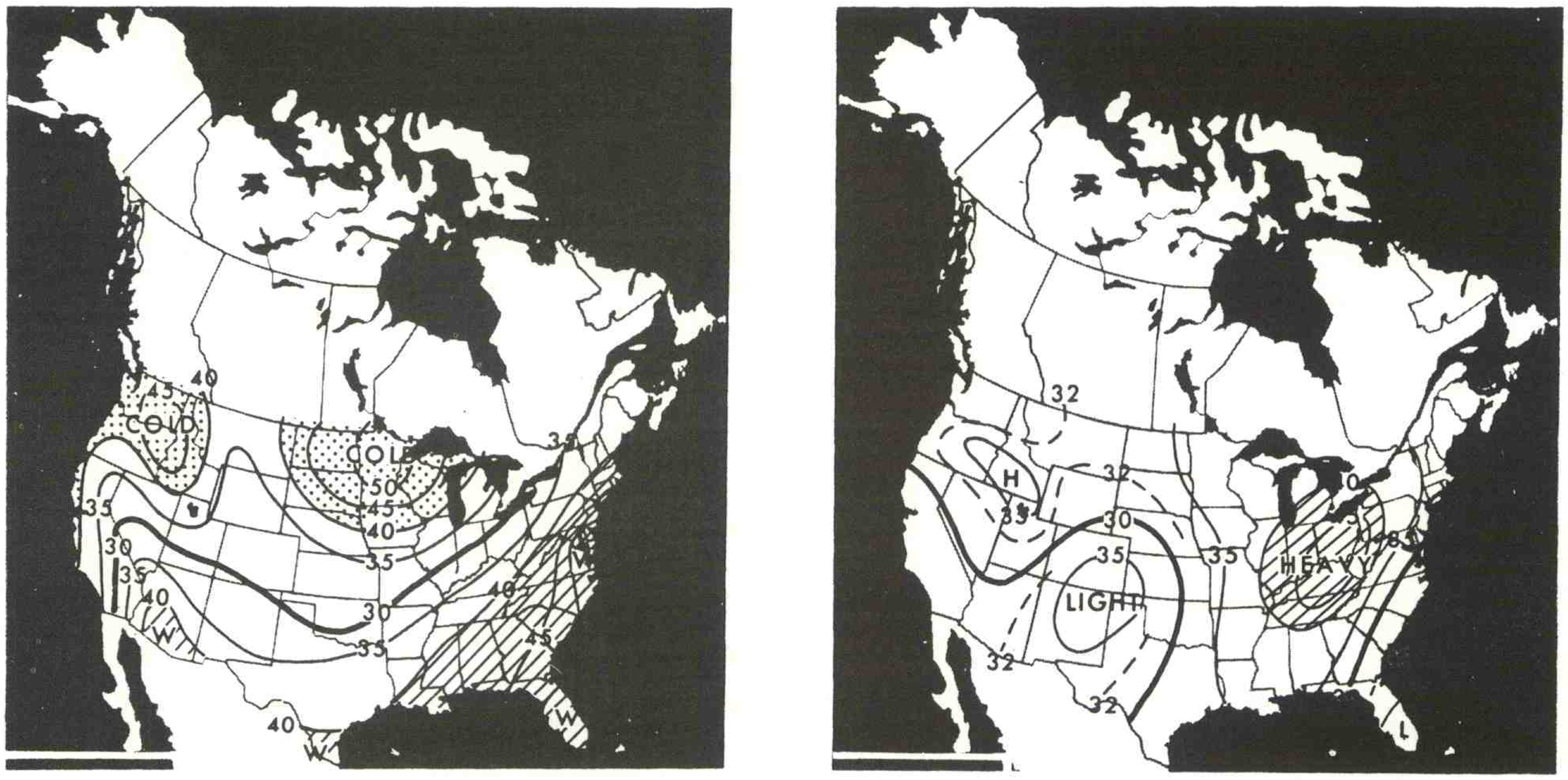
6.5.1 Anomaly History and Teleconnection (Wagner)

Seasonal mean temperature and precipitation anomaly maps have now been produced for all overlapping 3-month periods from January-March 1947 to March-May 1990. These maps, along with corresponding seasonal mean 700 mb height and anomaly maps, are available to forecasters for selecting specification analogs in making seasonal forecasts. This is the first consistent set of seasonal mean height, temperature, and precipitation anomalies that are being computed from the same reference normals for the 1947 - 1990 period.

6.5.2 Teleconnections (Wagner)

The data base from which teleconnection patterns are computed now extends from January 1947 - March 1989. Teleconnection maps are routinely produced on a Versatec printer in support of CAC's 6-10 day and 30-day forecast operations. These maps are also produced for NMC/Meteorological Operations Division in their 3-, 4-, and 5-day forecast operation. An extensive set of teleconnection maps for each month of the year is now available for use by forecasters. In addition, teleconnection maps for all useful locations in the Northern Hemisphere, north of 20^{o}N latitude, have now been produced on microfilm for the months December through August (1947 - 1989).

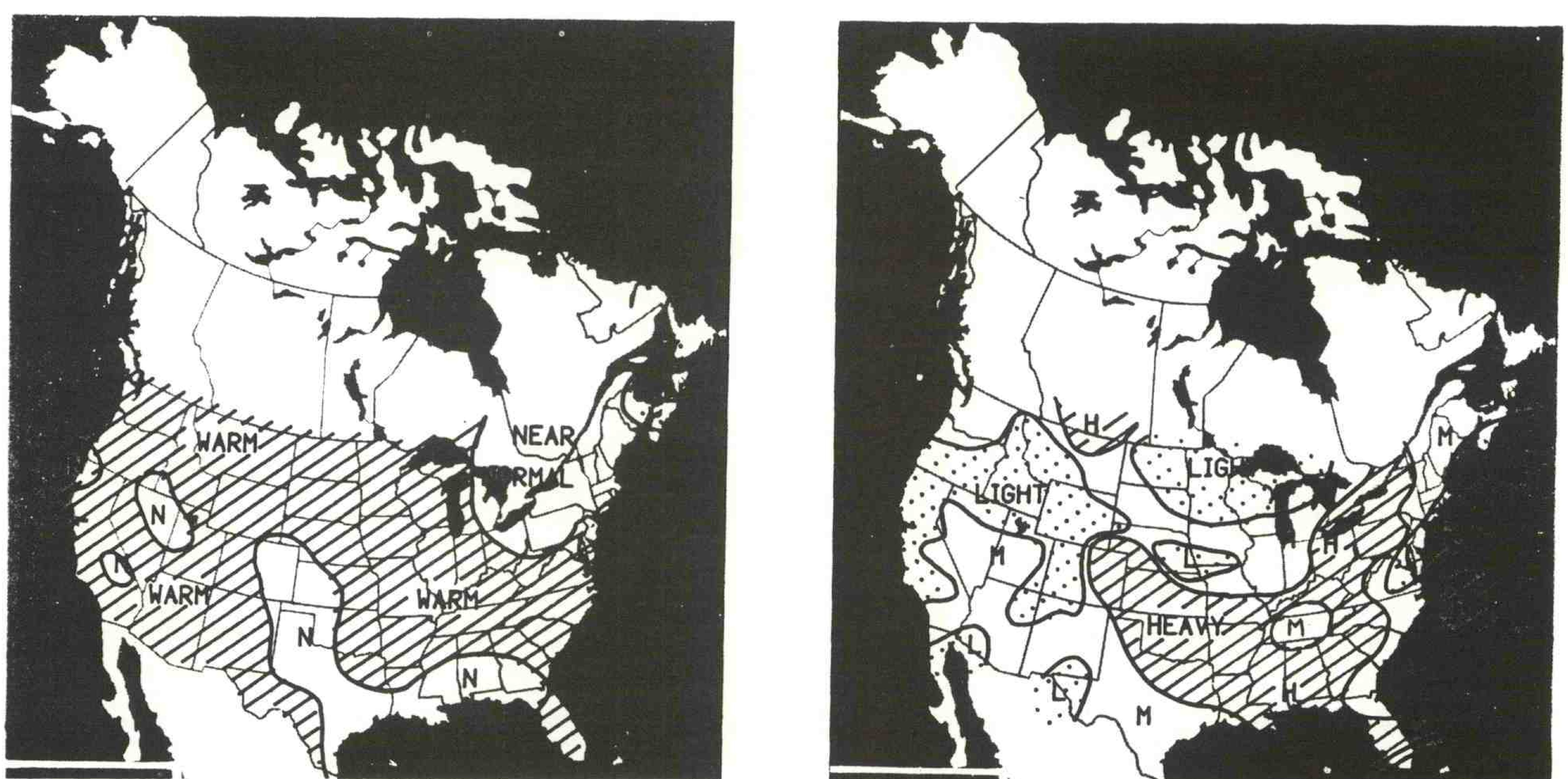
90-DAY OUTLOOK FOR DECEMBER 1989 THROUGH FEBRUARY 1990



TEMPERATURE PROBABILITIES

PRECIPITATION PROBABILITIES

OBSERVED FOR DECEMBER 1989 THROUGH FEBRUARY 1990



TEMPERATURE

PRECIPITATION

Figure 39 CAC's seasonal temperature and precipitation probability forecast for December 1989-February 1990 (top). Observed temperature and precipitation for December 1989-February 1990 (bottom).

7. SUMMARIES

7.1 Climate and Global Change Program (Rodenhuis, Ropelewski, Leetmaa, Reynolds, Miller)

CAC is a participant in a number of FY 1990 Tier I Projects under the NOAA Climate and Global Change Program. These include: Ozone (with ERL), Vegetation Index (with NESDIS), Climate Data Assimilation System (with NMC), Diagnostics (with ERL), Perspectives (with NCDC), and Global Precipitation Climatology Project (with WMO/WCRP). In addition, a Tier II proposal, entitled "Implementation of the Ocean Component of an Operational Coupled Ocean-Atmosphere System" (Leetmaa, CAC), was funded for the last 6 months of FY 1990.

The primary focus of Climate and Global Change activities is on climate diagnostics, climate monitoring, climate trends, and ocean modeling. The accomplishments for related tasks are described in preceding sections of this report. They include: Sections 1.2.3; 2.1.2, 2.1.3, 2.1.5, 2.2.1, 2.2.2; 3.1.1; and 4.2.1.

7.2 TOGA Activities (Diagnostics Branch Staff)

The primary focus of TOGA activities is on operational monitoring of the ENSO and oceanic-atmospheric fluctuations. The accomplishments for related tasks are described in preceding sections of this report. They include: Sections 1.1.2, 1.1.4, 1.2.4.1, 1.2.5; 2.1.1, 2.1.6, 2.3.1 and 2.4.1.

The TOGA Panel was briefed (by Ropelewski) on the current state of the Southern Oscillation and on the CAC Forecast Forum and related activities (December 12, 1989). CAC staff (Rodenhuis, Leetmaa, and Ropelewski) participated in an a TOGA Program Office sponsored Workshop on ENSO Prediction Centers (June 11-12, 1990). Also, papers were presented (by Reynolds) on ocean models and data assimilation before the Ad Hoc Panel on TOGA XBT Strategy and at the TOGA Scientific Conference (Honolulu, HI, July 13-20, 1990).

7.3 EPOCS Activities (Diagnostics Branch Staff)

The primary focus of EPOCS activities is on diagnostic studies of the tropical ocean-atmosphere. The accomplishments for related tasks are described in preceding sections of this report. They include: Sections 1.1.1, 1.1.3, 1.2.1, 1.2.2, and 1.2.4.2.

A FY 1990 EPOCS proposal, entitled "Analysis of the Global SO Signal" (Ropelewski, P.I.), was approved. Proposals that were submitted to the EPOCS Program for support in FY 1991 included: "Comparison of NMC Model Precipitation Forecasts and Satellite-Based Rainfall Estimates in the Tropics" (Janowiak, P.I.); "Tropical Convection and Associated Global Circulation Changes" (Ropelewski and Chelliah, P.I.'s); and "Atmospheric Teleconnection Dynamics During the 1986-90 ENSO Cycle" (Mo and Rasmusson, P.I's).

A paper was presented (by Reynolds) on the NMC operational surface fluxes at the EPOCS Annual Meeting (Miami, FL, January 18-19, 1990).

7.4 Bilateral Activities

7.4.1 U.S.-Braziian Bilateral Agreement (Kousky)

Under the auspices of the U.S. - Brazil Bilateral Agreement for Science and Technology, 3 scientists from the Brazilian Institute for Space Research completed working visits at NMC's South American "desk" and returned to Brazil. They are: Ms. C. Studzinski (Nov. 1989 - Feb. 1990); Ms. C. Uvo (Jan. - May 1990); and Ms. A. C. Perella (June - Aug. 1990). In August, Ms. Odete Chiesa, Brazilian Weather Service, started a four month working visit. All of the visiting scientists participated in forecast evaluation studies and in the preparation of numerical forecast discussions, which are disseminated on the Global Telecommunications System (GTS) to all South American countries.

Daily discussions and forecasts were prepared (by Kousky) which were distributed to South American countries via the GTS. Also, a description of the current climate anomalies in the tropical Pacific were prepared each month (by Kousky) and disseminated to South American countries. In addition, Kousky was a co-organizer of a Workshop on Numerical Weather Prediction [held at INPE, Sao Jose dos Campos, Brazil (April 2-6, 1990)], and he also participated in the First Working Group Meeting under the U.S./Brazil Science and Technology Initiative in the areas of Oceanography and Meteorology [Sao Jose dos Campos, Brazil (August 22-24, 1990)].

7.4.2 U.S.-Soviet Bilateral Agreement (Rodenhuis, Livezey, Ropelewski)

Four Soviet scientists attended the Fourteenth Annual Climate Diagnostics Workshop, in La Jolla, CA, October 16-20, 1989. Three of the Soviet scientists subsequently visited the CAC (November 25-30, 1989). A CAC scientist (Livezey) visited the World Data Center at Obninsk in August 1990.

A Soviet-sponsored Workshop on "The Diagnosis and Prediction of Short-Term Climate Variations" was held (Nov. 13-17, 1989) in Moscow, U.S.S.R. The U.S. delegation was headed by C. Ropelewski and also included: D. Rodenhuis and R. Livezey (NMC/CAC), H. van den Dool (University of Maryland), M. Wallace (University of Washington), and D. Gutzler (AER Inc).

Plans were completed for an exchange and joint project with the USSR Dept. of Climate Monitoring and Probabilistic Forecasting, Hydrometeorological Research Center. The exchange and work will focus on the capabilities of two objective forecast systems. Working visits to Moscow have now been made by CAC scientists (R. Livezey, August 1990; A. Barnston, September 1990). Reciprocal visits will be made to the CAC by several Soviet scientists in January 1991.

7.5 World Climate Program Activities

7.5.1 Climate Systems Monitoring (Ropelewski, Rodenhuis)

CAC staff (Rodenhuis, Ropelewski) participated in a WMO/Climate Change Detection Project Planning Meeting (Silver Spring, MD, January 1990). Project goals, milestones and a budget were drafted at this meeting. This project is an outgrowth of the Commission on Climatology Meeting (Lisbon, Portugal, April 1989). Another meeting is planned for Toronto, Canada (November 1990).

CAC supplies a large portion of the material published by the World Climate Programme in its Climate System Monitoring (CSM) Monthly Bulletin. In addition, C. Ropelewski is an active participant at the CSM's Annual Meeting.

7.5.2 Global Precipitation Climatology Project (Janowiak, Arkin)

The Global Precipitation Climatology Project (GPCP) Manager, P. Arkin, was transferred to the NOAA/ Office of Climatic and Atmospheric Research in November 1989. Prior to his departure, discussions were held with NESDIS regarding Tier II proposals for support of calibration/validation activities and rainfall estimation from microwave sensors.

A number of GPCP-related activities (by J. Janowiak) occurred during the year, under Climate and Global Change support. These included: participation at a meeting, held at the British Meteorological Office, to plan the GPCP/ Algorithm Intercomparison Project II (April 1990); a visit to the Global Precipitation Climatology Center at the German Weather Service, Offenbach, FRG (May 1990); participation at a TRMM Data Management Meetings at NASA/Goddard (December 1989 and June 1990); and participation at a NOAA Precipitation Science Team Meeting, Camp Springs, MD (June 1990).

7.5.3 Global Energy and Water Experiment (GEWEX) (Janowiak, Arkin)

A paper, describing the potential applications of IR threshold rainfall estimation techniques in middle and high latitudes, was presented (by Arkin) at a GEWEX Working Group Meeting on Precipitation (NASA/Goddard Space Flight Center, October 1989). Also, training was received (by J. Janowiak) on the use of a "WETNET" workstation (NASA/Marshall Space Flight Center, February 1990).

7.5.4 Intergovernmental Panel for Climate Change (IPCC) (Ropelewski)

Input for an IPCC Report (Working Group 1, Chapter 7) was revised and submitted to the principal authors. CAC was represented (by Ropelewski) at the IPCC Authors Workshop, held in Worcestershire, U.K., (Nov. 29-Dec. 1, 1989).

7.5.5 Commission on Climatology (CCl) (Rodenhuis)

A WMO/CCl Meeting was held in Geneva, Switzerland (April 1990). It was attended by D. Rodenhuis, who is a member of the Advisory Working Group and Rapporteur for climate change. He is also the Chairman of the Working Group of Climate Rapporteurs for the WMO/CAS.

7.6 National Weather Service Programs

7.6.1 Data Management (Ropelewski)

CAC participated (Ropelewski) on the NMC Committee on Data Base Management and provided input to the Plan. A meeting was held NWS Headquarters to coordinate the National Weather Service's contribution to the program.

7.6.2 ASOS Climate Working Group (Ropelewski, Rodenhuis)

An ASOS Climate Working Group report was drafted, revised, and distributed to the ASOS Project Office and Working Group members. The Project Office response to the report was received and has been distributed to the Working Group for comment.

Meetings were attended (by Ropelewski, CAC and Canfield, U. of Maryland) to coordinate NMC input to the NOAA Data Directory Project. Data Information Forms for a representative sample of CAC products were completed and submitted.

The ASOS Steering Group was briefed (by Ropelewski) on the activities of the Climate Working Group (December 15, 1989). Also, CAC staff (Rodenhuis and Ropelewski) met with representatives of the ASOS Program Office in Siver Spring, MD (May 31, 1990). A strategy was developed for reviewing a NWS/ASOS Climate Policy and Plan.

7.7 Annual Climate Diagnostics Workshop

7.7.1 Fourteenth Annual Climate Diagnostics Workshop (Rodenhuis, Janowiak)

The NMC/Climate Analysis Center and Scripps Institution of Oceanography were co-sponsors of the Fourteenth Annual Climate Diagnostics Workshop held in La Jolla, CA (October 16-20, 1989). These Workshops provide a forum for researchers to present recent results and to exchange ideas on a variety of climate topics. This meeting focused on: ENSO analysis and prediction, ocean-atmosphere interaction, and global climate variability. There were 89 papers presented; a Proceedings was published and distributed in March 1990.

7.7.2 Fifteenth Annual Climate Diagnostics Workshop (Rodenhuis, Ropelewski)

Arrangements were completed to hold the Fifteenth Annual Climate Diagnostics Workshop in Asheville, NC. The NESDIS/National Climatic Data Center has agreed to co-host the Workshop which is scheduled for October 29 - November 2, 1990. Invititations to the Workshop were mailed and a workshop announcement was published in the Bulletin of the AMS (June 1990).

8. BIBLIOGRAPHY

8.1 Journal Articles

Arkin, P. A., and P. E. Ardanuy, "Estimating climatic-scale precipitation from space: A review," Journal of Climate, 2, 11, Nov. 1989, pp. 1229-1238.

Barnston, A. G. and R. E. Livezey, "A closer look at the effect of the 11-year solar cycle and the quasi-biennial oscillation on Northern Hemisphere 700 mb height and extratropical North American surface temperature," Journal of Climate, 2, 11, Nov. 1989, pp. 1295-1313.

Chelliah, M., "The global climate for June-August 1989: A season of near normal conditions in the tropical Pacific," Journal of Climate, 3, 1, Jan. 1990, pp. 138-162.

Chen, W-Y., "Interannual variability of skill of NMC medium-range forecasts over the Pacific/North America sector," Monthly Weather Review, 118, 1, Jan. 1990, pp. 179-188.

Epstein. E. S. and A. G. Barnston, "A precipitation climatology of 5-day periods," Journal of Climate, 3, 2, Feb. 1990, pp.218-236.

Farrara, J. D., M. Ghil, C. R. Mechoso, and K. Mo, "Empirical orthagonal functions and multiple flow regimes in the Southern Hemisphere winter," Journal of the Atmospheric Sciences, 46, Oct. 1989, pp. 3219-3223.

Halpert, M. S., "The global climate for September-November 1989: Normal tropical Pacific conditions continue," Journal of Climate, 3, 3, Mar. 1990, pp. 394-413.

Janowiak, J. E., "The global climate for December 1989-February 1990: Extreme temperature variations in North America, persistent warmth in Europe and Asia, and the return of ENSO-like conditions in the western Pacific," Journal of Climate, 3, 6, June 1990, pp. 685-709.

Kann, D. M., R. A. Petersen, and G. J. DiMego, "The effect of surface observations on low-level temperatures in the National Meteorological Center regional analysis scheme," Monthly Weather Review, 118, 3, Mar. 1990 pp. 772-777.

Kousky, V. E. and C. F. Ropelewski, "Extremes in the Southern Oscillation and their relationship to precipitation anomalies with emphasis on the South American Region," Revista Brasileira de Meteorologia, 4, pp.351-353.

Le Comte, D. M., "The weather of 1989: Highlights in the U. S.," Weatherwise, 43, Feb. 1990, pp. 8-15.

Le Comte, D. M., "The weather of 1989: Highlights around the world," Weatherwise, 43, Feb. 1990, pp. 16-18.

Livezey, R. E., "Variability of skill of long-range forecasts and implications for their use and value," Bulletin of the American Meteorological Society, 71, 3, Mar. 1990, pp. 300-309.

Livezey, R. E., A. G. Barnston, and B. K. Neumeister, "Mixed analog/persistence prediction of seasonal mean temperatures for the U.S.A.," International Journal of Climatology, 10, 1990, pp. 329-340.

Nagatani, R. M., A. J. Miller, M. E. Gelman, and P. A. Newman, "A comparison of Arctic lower stratospheric winter temperatures for 1988-89 with temperatures since 1964," Airborne Arctic Stratospheric Expedition (AASE), Geophysical Research Letters, 17, 4, AASE Special Issue, March 1990, Supplement, pp. 333-336.

Newman, P. A., L. R. Lait, M. R. Schoeberl, and R. M. Nagatani, "Stratospheric temperatures during the 1988-89 Northern Hemisphere winter," Geophysical Research Letters, 17, 4, AASE Special Issue, March 1990, Supplement, pp. 329-332.

Rasmusson, E. M., X. Wang, and C. F. Ropelewski, "The biennial component of ENSO variability," Journal of Marine Systems, 1, 1990, pp. 71-96.

Reynolds, R. W., C. K. Folland, and D. E. Parker, "Biases in satellite-derived sea-surface-temperature data," Nature, 341, 1989, pp. 728-731.

Rogers, E., G. J. DiMego, J. P. Gerrity, R. A. Petersen, B. D. Schmidt, and D. M. Kann, "Data assmilation experiments using GALE data at the National Meteorological Center," Bulletin of the American Meteorological Society, 71, 3, Mar. 1990, pp. 319-333.

Ropelewski, C. F., "Monitoring large-scale cryosphere/atmosphere interactions," Advances in Space Research, 9, 7, 1990, pp. 213-218.

Shin, K-S., G. R. North, Y-S. Ahn, and P. A. Arkin, "Time scales and variability of area-averaged tropical oceanic rainfall," Monthly Weather Review, 118, 7, July 1990, pp. 1507-1516.

Tracton, M. S., "Predictability and its relationship to scale interaction processes in blocking," Monthly Weather Review, 118, 8, Aug. 1990, pp. 1666-1675.

van den Dool, H. M., "A new look at weather forecasting through analogues," Monthly Weather Review, 117, 10, Oct. 1989, pp. 2230-2247.

van den Dool, H. M., "1988 in de Bilt het warmste jaar van de eeuw: Hoe uitzonderlijk is deze warmte?," Zenit, 16, 1989, pp. 433-437.

van den Dool, H. M., " Time-mean precipitation and vertical motion patterns over the United States," Tellus, 42A, 1990, pp. 51-64.

van den Dool, H. M. and S. Saha, "Frequency dependence in forecast skill," Monthly Weather Review, 118, 1, Jan. 1990, pp. 128-137.

Vautard, R., K. Mo and M. Ghil, "Statistical significance test for transition matrices of atmospheric Markov chains," Journal of the Atmospheric Sciences, 47, Aug. 1990, pp. 1926-1931.

Wagner, A. J., "The weather of 1989: Northern Hemisphere circulation," Weatherwise, 43, Feb. 1990, pp. 19-22.

8.2 Articles in Non-Refereed Literature *

Arkin. P. A., "Estimation of large-scale tropical rainfall for TOGA," Proceedings of the Western Pacific International Meeting and Workshop on TOGA/COARE, Noumea, New Caldonia, 1989, pp. 561-570.

Arkin, P. A. and J. E. Janowiak, "Observing precipitation from space," Proceedings of the Symposium on Global Change Systems, Special Sessions on Climate Variations and Hydrology, Anaheim, CA, February 5-9, 1990, pp. 116-121.

Barnston, A. G., and R. E. Livezey, "A statistical evaluation of an association between the QBO and the Northern Hemisphere lower atmosphere," Proceedings of the 11th AMS Conference on Probability and Statistics, Monterey, CA, October 2-6, 1989, pp. 318-324.

Barnston, A. G. and R. E. Livezey, "Statistical prediction of January-February mean North American climate from an 11-year solar cycle and ENSO, for west QBO phase years," Proceedings of the 14th Annual Climate Diagnostics Workshop, La Jolla, CA, October 16-20, 1989, pp. 333-338.

Barnston, A. G. and R. E. Livezey, "The Northern Hemisphere mean January-February flux-climate relationship -- 1989 update," Proceedings of the Workshop on Mechanisms for Tropospheric Effects of Solar Variability and the Quasi-Biennial Oscillation, Boulder, CO, 1989, pp. 174-181.

Barnston, A. B. and C. F. Ropelewski, "Prediction of ENSO episodes using canonical correlation analysis," Proceedings of the 14th Annual Climate Diagnostics Workshop, La Jolla, CA, October 16-20, 1989, pp. 307-312.

Bonner, W. D., E. Kalnay, J. D. Stackpole and V. E. Kousky, "Numerical weather prediction for the Southern Hemisphere at NMC Washington," Extended Abstracts of the Third International Conference on Southern Hemisphere Meteorology and Oceanography, Buenos Aires, Argentina, November 13-17, 1989, pp. 4-12.

Campana, K. A., P. M. Caplan, G. H. White, S-K. Yang, and H. M. Juang, "Impact of changes to cloud parameterization on the forecast error of NMC's global model," Proceedings of the 7th AMS Radiation Conference, San Francisco, CA, July 23-27, 1990, pp. J152-J158.

Chelliah, M. and P. A. Arkin, "Interannual variability and trends indicated by OLR," Proceedings of the 14th Annual Climate Diagnostics Workshop, La Jolla, CA, October 16-20, 1989, pp. 216-221.

Chen, W-Y., "Dynamical prediction in the extended range employing low-frequency PNA mode," Proceedings of the 14th Annual Climate Diagnostics Workshop, La Jolla, CA, October 16-20, 1989, pp. 324-327.

* In this Section, 40 of the references also included a presentation at a formal scientific meeting.

Epstein, E. S., "Expected number of hits for multiple categorical forecasts of precipitation occurrences," Proceedings of the 11th AMS Conference on Probability and Statistics, Monterey, CA, October 2-6, 1989, pp. 129-131.

Halpert, M. S., P. A. Arkin, C. F. Ropelewski, and R. Tomlinson, "The development and utilization of an AVHRR-based vegetation index for climate monitoring," Proceedings of the 14th Annual Climate Diagnostics Workshop, La Jolla, CA, October 16-20, 1989, pp. 211-215.

Hughes, F. D., "Skill of medium range forecasts," NMC Office Note No. 364 Feb. 1990, 114 pp.

Janowiak, J. E., P. A. Arkin and D. Davidowicz, "Variations in tropical rainfall, as inferred from satellite observations of cloud-top temperature," Proceedings of the 14th Annual Climate Diagnostics Workshop, La Jolla, CA, October 16-20, 1989, pp. 8-11.

Junker, N. W., Hoke, J. E., Sullivan, B. E., Petersen, R. A., and F. D. Hughes, "Seasonal and geographical variations in predicting precipitation by two of NMC's operational baroclinic models," Proceedings of the Third Workshop on Operational Meteorology, AES, Montreal, Quebec, May 2-4, 1990, pp. 221-228.

Kann, D. M., S-K. Yang, and A. J. Miller, "Atmospheric energetics and earth radiation budget; Proceedings of the 7th AMS Radiation Conference, San Francisco, CA, July 23-27, 1990, pp. J129-J131.

Kayano, M. T. and V. E. Kousky, "Southern Hemisphere blocking climatology," Extended Abstracts of the Third International Conference on Southern Hemisphere Meteorology and Oceanography, Buenos Aires, Argentina, November 13-17, 1989, pp. 132-133.

Kayano, M. T., V. E. Kousky, C. D. Studzinski, and P. L. S. Dias, "Intraseasonal variations in Brazil precipitation during the summer of 1989/1990," (In Portuguese), Climanalise, 5, No. 4, 1990, pp. 40-50.

Kayano, M. T. and V. E. Kousky, "Further evidence of the El Niño influence on the Brazilian climate variations," Extended Abstracts of the Third Symposium on Meteorological Aspects of Tropical Droughts with Emphasis on Long-Range Forecasting, Niamey, Niger, Apr. 30 - May 4, 1990, pp. 95-101.

Klein, W. H. and E. S. Epstein, "Six-ten day probability forecasts of daily precipitation frequency," Proceedings of the 14th Annual Climate Diagnostics Workshop, La Jolla, CA, October 16-20, 1989, pp.350-356.

Klein, W. H., E. S. Epstein, and T. J. Perrone, "Specifying probability anomalies of daily precipitation frequency during 5-day periods," Proceedings of the 11th AMS Conference on Probability and Statistics, Monterey, CA, October 2-6, 1989, pp. 35-39.

Kousky, V. E., "Recent extremes in the Southern Oscillation: Evolution of oceanic and atmospheric anomalies and their impact on precipitation," (Invited paper.), Extended Abstracts of the Third International Conference on Southern Hemisphere Meteorology and Oceanography, Buenos Aires, Argentina, November 13-17, 1989, pp. 357-360.

Kousky, V. E. and M. Ji, "Tropical sea level pressure variations and related oceanic and atmospheric anomaly patterns," Extended Abstracts of the Third International Conference on Southern Hemisphere Meteorology and Oceanography, Buenos Aires, Argentina, November 13-17, 1989, pp. 404-406.

Kousky, V. E. and C. F. Ropelewski, "Atmospheric circulation changes associated with extremes of the Southern Oscillation during 1986-1989," Proceedings of the Fourteenth Annual Climate Diagnostics Workshop, La Jolla, CA, October 16-20, 1989, pp. 1-7.

Leetmaa, A., "Operational ocean modeling for climate and global change: Status and priorities for future work," CAC Internal Report, May 1990, 12pp.

Lehman, R. E., "Quick projections of monthly outcomes system," Preprint Volume of the Sixth AMS International Conference on Interactive Information and Processing Systems, Anaheim, CA, February 5-9, 1990, pp. 201-205.

Lehman, R. L., "Needs related to climate information," Sub-Task 3: Trends in National Needs related to Economic Efficiency and Competetiveness, NOAA Strategic Plan, August 1990.

Livezey, R. E., "Teleconnection studies and the empirical description of the low-frequency quasi-stationary circulation," Proceedings of the Fourth International Meeting on Statistical Climatology, Rotorua, New Zealand, 1989, pp. 79-86.

Livezey, R. E., "Variability of skill of long-range forecasts and implications for their use and value," Proceedings of the 14th Annual Climate Diagnostics Workshop, La Jolla, CA, October 16-20, 1989, pp. 301-306.

Miskus, D. and J. D. Laver, "Near-real time weekly assessments of global climate anomalies," Drought Network News, 2, 1, International Drought Information Center, University of Nebraska, Lincoln, NE, Feb. 1990, pp. 14-16.

Mo, K., J. R. Zimmerman, E. Kalnay, and M. Kanamitsu, "A GCM study on the 1988 U. S. drought," Proceedings of the Fourteenth Annual Climate Diagnostics Workshop, La Jolla, CA, October 16-20, 1989, pp. 245-249.

Newman, P. A., L. R. Lait, M. R. Schoeberl, R. M. Nagatani, and A. J. Krueger, "Meteorological Atlas of the Northern Hemisphere Lower Stratosphere for January and February 1989 during the Airborne Arctic Stratospheric Expedition," NASA Technical Memorandum 4145, November 1989, 185 pp.

O'Lenic, E. A., "Modernization of long-range prediction operations at NMC," Proceedings of the 14th Annual Climate Diagnostics Workshop, La Jolla, CA, October 16-20, 1989, pp. 381-384.

Reynolds, R. W., "Climatological sea surface temperature signals from satellites," Proceedings of the Symposium on Global Change Systems, Special Sessions on Climate Variations and Hydrology, Anaheim, CA, February 5-9, 1990, pp. 123-126.

Reynolds, R. W. and A. Leetmaa, "Evaluation of NMC's operational surface fluxes in the tropical Pacific," Proceedings of the Western Pacific International Meeting and Workshop on TOGA/COARE, Noumea, New Caledonia, May 24-30, 1989, pp. 535-541.

Roads, J. O. and N. Maisel, "Numerical model precipitation forecasts," Proceedings of the 14th Annual Climate Diagnostics Workshop, La Jolla, CA, October 16-20, 1989, pp. 313-318.

Ropelewski C. F. "Large-scale circulation, the Southern Oscillation, and drought," Extended Abstracts of the Third Symposium on Meteorological Aspects of Tropical Droughts with Emphasis on Long-Range Forecasting, Niamey, Niger, Apr. 30-May 4, 1990, pp. 1-6.

Ropelewski, C. F. and M. S. Halpert, "Uncovering North American temperature and precipitation patterns associated with the Southern Oscillation," Proceedings of the 6th Annual PACLIM Conference, Pacific Grove, CA, 1989, pp. 42-43.

Ropelewski, C. F. and M. S. Halpert, "Interannual variability and the detection of climate trends," Proceedings of the Symposium on Global Change Systems, Special Sessions on Climate Variations and Hydrology, Anaheim, CA, February 5-9, 1990, pp. 123-126.

Ropelewski, C. F., M. S. Halpert and E. M. Rasmusson, "Interannual climate variability in the global tropics," Proceedings of the 4th International Meeting on Statistical Climatology, Rotorua, New Zealand, 1989, pp. 252-254.

Ropelewski, C. F., M. S. Halpert and E. M. Rasmusson, "Biennial variability in tropical SST and winds," Proceedings of the Fourteenth Annual Climate Diagnostics Workshop, La Jolla, CA, October 16-20, 1989, pp. 84-90.

Staff, Climate Analysis Center and National Climatic Data Center, " Climate Assessment for 1989: Selected Indicators of Global Climate," Camp Springs, MD, March 1990, 21 pp.

Uvo, C. R. B., and V. E. Kousky, "Correlation between estimated precipitation by satellite and observed precipitation over the state of Ceara," (In Portuguese), Climanalise, 5, No. 5, 1990, pp. 38-42.

van den Dool, H. M., "Dynamic forecast of the next month's flow," Proceedings of the 14th Annual Climate Diagnostics Workshop, La Jolla, CA, October 16-20, 1989, pp. 319-323.

Wagner, A. J., "Medium and long-range forecasting at the National Meteorological Center," Proceedings of the 14th Annual Climate Diagnostics Workshop, La Jolla, CA, Oct. 16-20, 1989, pp. 375-380.

Wang, X. and E. M. Rasmusson, "ENSO-related variability as revealed by singular spectrum analysis," Proceedings of the 14th Annual Climate Diagnostics Workshop, La Jolla, CA, October 16-20, 1989, pp. 91-95.

Yang, S. K., H. M. Juang, K. A. Campana, and A. J. Miller, "Validating cloud field and outgoing longwave radiation generated by NMC medium-range forecast model with ERBE and Air Force real time nephanalysis," Proceedings of the 7th AMS Radiations Conference, San Francisco, CA, July 23-27, 1990, pp. 145-148.

8.3 Presentations at Formal Scientific Meetings *

Barnston, A. G., "January-February tropospheric climate for the Northern Hemisphere and the 11-year solar cycle, the QBO and the Southern Oscillation," presented at the International Conference on the Climate Impact of Solar Variability, NASA/GSFC, Greenbelt, MD, April 25, 1990.

Barnston, A. G., "The Statistical testing of association between the 11-year solar cycle, the QBO, and the climate," presented at the XXVIII COSPAR Plenary Meeting, The Hague, Netherlands, June 29, 1990.

Cai, M., and H. M. van den Dool, "Symbotic relationship between low frequency waves and traveling storm tracks," presented at the NCAR Workshop on Numerical Long Range Prediction, Boulder, CO, June 4-8, 1990.

Chen, W-Y., "Interannual variability of skill of NMC medium-range forecasts and feasibility of dynamical forecasting in the extended range," presented at the Twelfth Conference on Weather Analysis and Forecasting, Monterey, CA, October 2-6, 1989.

Chen, W-Y., "Effect of transient eddies on blocking flow: GCM experiments," presented at the NCAR Workshop on Numerical Long Range Prediction, Boulder, CO, June 4-8, 1990.

Ebisuzaki, W., "Monte Carlo forecasting of blocking developments," presented at the NCAR Workshop on Numerical Long Range Prediction, Boulder, CO, June 4-8, 1990.

Gelman, M. E., "Radiosonde intercomparisons and adjustments applied at NMC," presented at the Upper-Air Measurements and Instrumentation Workshop at Wallops Island, VA, November 14-15, 1989.

Gelman, M. E., "Solar cycle relationships between upper stratosphere temperature and ozone," presented at the Seventh International Symposium on Solar-Terrestrial Physics, the Hague, the Netherlands, June 1990.

Heddinghaus, T. R., "Monitoring and dissemination of drought conditions at the Joint Agricultural Weather Facility," presented at the Drought Management and Planning Seminar & Workshop, Denver, CO, May 30-June 1, 1990.

Halpert, M. S., "The development and utilization of an AVHRR-based Vegetation Index for climate monitoring," presented at the Workshop on the Use of Satellite-Derived Vegetation Indices in Weather and Climate Prediction Models," Camp Springs MD, February 26-27, 1990.

Hughes, F. D., "Medium-range forecasts at NMC," presented at the Workshop on Numerical Weather Prediction, INPE, Sao Jose dos Campos, Brazil, April 2-6, 1990.

* There were 40 additional presentations that were also published in a Proceedings or a Preprint Volume of a Formal Scientific Meeting. These 40 references are listed only in Section 8.2.

Kousky, V. E., "Current state of the Southern Oscillation," (Invited talk), presented at the Third International Conference on Southern Hemisphere Meteorology and Oceanography, Buenos Aires, Argentina, November 13-17, 1989.

Kousky, V. E., "Precipitation anomalies associated with extremes of the Southern Oscillation," presented at the Workshop on Long Range Climate Prediction, Montevideo, Uruguay, November 20-21, 1989.

Kousky V. E. "Atmospheric circulation features prior to and during the 1988 Drought, (Invited talk), presented at the Workshop on the 1988 North American Drought, University of Maryland, College Park, MD, April 30 - May 2, 1990.

Laver. J. D., "Climate services issues relevant to state climatologists," presented at the Annual Meeting of the American Association of State Climatologists, Atlantic City, NJ, August 6-8, 1990.

LeComte, D. M., "Monitoring drought at the JAWF," presented at the 15th Annual Natural Hazards Research and Applications Workshop, Boulder, CO, July, 18, 1990.

Leetmaa, A., " The role of ocean and atmospheric models in the analysis and prediction of sea level variability," presented at the Joint Oceanographic Institutions Sea Level Workshop, Woods Hole, MA, May 2-4, 1990.

Lehman, R. L., "Applications of NWS Research to the Gas Industry", Annual Meeting of the National Association of Regulatory Utility Commissioners, Washington, D.C., February 26, 1990.

Lehman, R. E., "New climate impact assessment tools," presented at the U.S. Dept. of Energy Pre-Summer Energy Assessment Conference, Washington, D.C., April 27, 1990.

Livezey, R. E., "Variability of skill of long-range forecasts and implications for their use and value," presented at the Workshop on Diagnosis and Forecasting of Short-Term Climate Variations on the Season-Year-Decade Time-Scale, Moscow, USSR, November 11-18, 1989.

Livezey, R. E., "Summer outlooks," presented at the U.S. Dept. of Energy Pre-Summer Energy Assessment Conference, Washington, D.C., April 27, 1990.

Miller, A. J., "A review of satellite observations of atmospheric ozone," (Invited paper), presented at the AMS Conference on Climate Variations, Anaheim, CA, February 6-9, 1990.

Miller, A. J., "Atmospheric Energetics," (Invited paper), presented at the SPIE Conference, Orlando, FL, April 1990.

Miller, A. J., "The ground-based network," (Invited paper), presented at the International School of Space Physics, Marseilles, France, August 1990.

Mo, K. C., "Singular spectral analysis and its applications," presented at the 11th Conference on Probability and Statistics in Atmospheric Sciences, Monterey, CA, October 1-5, 1989.

Mo, K. C., "Oscillatory modes in the Southern Hemisphere," presented at the Third International Conference on Southern Hemisphere Meteorology and Oceanography, Buenos Aires, Argentina, November 13-17, 1989.

Mo K. C., "A GCM study on the 1988 U.S. drought," (Invited talk), presented at the Workshop on the 1988 North American Drought, University of Maryland, College Park, MD, April 30- May 2, 1990.

Mo, K. C., "Impact of sea surface temperature anomalies on the skill of monthly forecasts," presented at NCAR Workshop on Long-Range Prediction, Boulder, CO, June 8, 1990.

O'Lenic, E., "Short-term climate prediction in the Great Lakes Region," presented at the Great Lakes Commission Symposium: Great Lakes Water Levels Forecasting and Statistics for Decision Making, Windsor, Ontario, Canada, May 17, 1990.

Reynolds, R. W., "NMC operational surface fluxes," presented at the Annual EPOCS Meeting, Miami, FL, January 18-20,1990.

Reynolds, R. W., " Data assimilation-tropical oceans," presented at the International TOGA Conference, Honolulu, Hi, July 16-20, 1990.

Rodenhuis, D. R., "Numerical prediction of climate anomalies at the CAC/NMC," presented at the Conference on the Diagnosis of Short-Term Climate Variations, Moscow, USSR, November 11-21, 1989.

Rodenhuis, D. R., "NOAA Climate Services," presented at the Annual Meeting of the American Association of State Climatologists, Atlantic City, NJ, August 6-8, 1990.

Ropelewski, C. F., "A review of global precipitation and surface temperature patterns associated with the Southern Oscillation," presented at the Workshop on the Diagnosis and Prediction of Short-Term Climate Variations, Moscow, USSR, November 13-17, 1989.

Ropelewski. C. F., "Natural climate variability and the Southern Oscillation," presented at the SW Connecticut State University Conference on Weather and Climate Variability, Danbury, CT, February 21-23, 1990.

Stefanski, R. J., "Estimation of county-level corn development and yield with CERES-MAIZE in the U. S. Corn Belt," presented at a poster session at American Society of Agronomy Meeting, Las Vegas, NV, October 15-20, 1989.

Tracton, M. S., "Predictability and its relationship to scale interaction processes in blocking," presented at the Twelfth AMS Conference on Weather Analysis and Forecasting, Monterey, CA, October 2-6, 1989.

Tracton, M. S., "Preliminary evaluation of quasi-operational DERF at CAC," presented at the NCAR Workshop on Numerical Long Range Prediction, Boulder, CO, June 4-8, 1990.

van den Dool, H. M. "Evaluation of skill of NWP, implication for long-range weather prediction," presented at the Workshop on Diagnosis and Forecasting of Short-Term Climate Variations on the Season-Year-Decade Time-Scale, Moscow, USSR, November 15, 1989.

van den Dool, H. M., "Mirror images of atmospheric flow," presented at the XVth Assembly of the European Geophysical Society, Copenhagen, Denmark, April 16-20, 1990.

van den Dool, H. M., "Toward forecasting the last 2 or 3 weeks of the next month," presented at the NCAR Workshop on Numerical Long Range Prediction, Boulder, CO, June 4-8, 1990.

van den Dool, H. M., "Medium and long-range prediction at CAC," presented at the Soil Conservation Service/NWS Technical Working Group, Salt Lake City, UT, August 15, 1990.

van den Dool, H. M., "Medium and long-range prediction at CAC," presented at the Colorado River Forecasting System Meeting, Salt Lake City, UT, August 16, 1990.

Yang, S-K., "Data archive and grid size considerations," presented at the 2nd CERES Science Team Meeting, NASA/Langley Research Center, Langley, VA, November 6-8, 1989.

8.4 Seminars and Briefings

Arkin, P. A., "Potential applications of IR threshold rainfall estimation techniques in high latitudes," presented at the GEWEX Working Group on Precipitation, NASA/GSFC, Greenbelt, MD, October 25-26, 1989.

Chelliah, M., "Interannual and long-term variability indicated by OLR," presented in conjunction with the Climate Analysis Center Seminar Series, NMC, Camp Springs, MD, October 31, 1989.

Chen, W-Y., "Preliminary results of DERF III experiments," presented at NMC Seminar Series, Camp Springs, MD, December 12, 1989.

Ebisuzaki, W., "Vertical tilts of tropospheric waves," presented at the CAC Seminar Series, Camp Springs, MD, December 7, 1989.

Epstein, E. S., "Improving on perfect progs," presented at the CAC Seminar Series, Camp Springs, MD, April 12, 1990.

Kousky, V. E., Lecture Series for a course on "Climate variability and its impact on the environment," presented at the University of Buenos Aires, Buenos Aires, Argentina, November 6-10, 1989.

Kousky, V. E., "ENSO update," presented before the TOGA Advisory Panel, Washington, D. C., September 18, 1990.

Laver, J. D., "Overview of CAC activities," presented at CAC and SIAS 90 (Summer Institute in Atmospheric Science) Seminar, Camp Springs, MD, June 11, 1990.

Lehman, R. E., "Modeling climate data sets by use of standard type III Gamma functions," presented at NMC Seminar Series, Camp Springs, MD, May 1, 1990.

Livezey, R. E., "Quasi-stationary circulations," Lecture for NMC Short Course on "Dynamics of Climate Variability," Camp Springs, MD, October, 1989.

Livezey, R. E., "Six-ten day, thirty-day and ninety-day outlooks," presented at a special Department of Energy Meeting on Fuel and Energy, Washington, D.C., December 23, 1989.

Livezey, R. E., "Some recent activities in long-range forecasting research at CAC," seminars presented at the Hadley Center for Climate Prediction and Research, Bracknell, UK, Aug. 8, 1990; at the Max Planck Institut fur Meteorologie, Hamburg, Germany, Aug. 14, 1990; and at the Hydrometeorological Center of the USSR, Moscow, USSR, Aug. 28, 1990.

Miller, A. J., "Monitoring the stratosphere," presented at the CAC Seminar Series, Camp Springs, MD, July 26, 1990.

Miskus, D., "PRESTO and other meteorological/climatological publications by the Climate Analysis Center," presented at the D.C. Chapter of the American Meteorological Society, Silver Spring, MD, November 16, 1989.

Miskus, D., "Drought in the West", presented at the Congressional Office of Technology and Assessment (OTA), Washington, D.C., May 24, 1990.

Mo, K. C., "1988 U. S. drought," presented at the University of Utah, Salt Lake City, UT, October 9, 1989.

Mo, K. C., "Atmospheric teleconnection dynamics during the 1986-1989 ENSO cycle," presented at the University of Buenos Aires, Buenos Aires, Argentina, November 9, 1989.

Mo, K. C., "A GCM study on the 1988 U. S. drought," presented at the University of Maryland Seminar Series, College Park, MD, January 25, 1990.

Mo, K. C., "Impact of SST anomalies on the skill of monthly forecasts," presented at the CAC Seminar Series, Camp Springs, MD, May 10, 1990.

Reynolds, R. W., "Global SST/ air-sea interaction," presented at the NMC Training Course for Oceanography, Camp Springs, MD, January 23 and 26, 1990.

Reynolds, R. W., "Ocean models and data assimilations," presented at the Ad Hoc Panel on TOGA XBT Strategy, Honolulu, HI, July 13, 1990.

Rodenhuis, D. R., "Program development plans for Regional Climate Centers and the scope and plans for climate prediction," presented at the NOAA Troika Meeting, NCDC, Asheville, NC, May 22-23, 1990.

Rodenhuis, D. R., "Report of the ASOS Climate Working Group," presented to the NAS/NRC Panel on NWS Modernization, Washington, D.C., September 4, 1990.

Rodenhuis, D. R., "Where do we (CAC) go from here?," presented at the CAC Seminar Series, Camp Springs, MD, September 13, 1990.

Ropelewski, C. F.,"Interannual climate variability, precipitation, and drought," presented at the NMC Training Course on Climate, Camp Springs, MD, October 31 and November 2, 1989.

Ropelewski, C. F., "The current state of the Southern Oscillation" and "The CAC ENSO Prediction Project," presented at the TOGA Panel Meeting, Washington, D.C., December 12, 1989.

Ropelewski C. F., "The CAC ENSO prediction project," presented at the NOAA Troika Meeting, NCDC, Asheville NC, May 22-23, 1990.

Sabol, P., "Determination of climate anomalies," presented at a CAC and SIAS (Summer Institute in Atmospheric Science) 90 Seminar, Camp Springs, MD, July 18, 1990.

Tracton, M. S., "Preliminary evaluation of CAC's DERF "spinoff" experiment: Quasi-operational extensions of the MRF to 15 days," presented at the CAC Seminar Series, Camp Springs, MD, May 17, 1990.

van den Dool, H. M., "Frequency dependence in forecast skill," presented at the University of Maryland, College Park, MD, October 5, 1989; and at the Scripps Inst. of Oceanography, La Jolla, CA, October 23, 1989.

van den Dool, H. M. "Dynamic prediction of the next month's flow," presented at the National Academy of Sciences, Moscow, USSR, November 17, 1989.

van den Dool, H. M., "Prospects for long-range prediction, presented at the NMC Training Course on the Dynamics of Climate Variability, Camp Springs, MD, November 28 and 30, 1989.

van den Dool, H. M., "Research in climate change," presented at the Royal Netherlands Meteorological Society, de Bilt, Netherlands, April 17, 1990.

van den Dool, H. M., "DERF and seasonal prediction," presented at the NOAA Troika Meeting, NCDC, Asheville, NC, May 22, 1990.

van den Dool, H. M., "Mirror images of atmospheric flow," presented at the CAC Seminar Series, Camp Springs, MD, July 12, 1990; and at the University of Utah, Salt Lake City, UT, Aug. 14, 1990.

Wagner, A. J., "Medium and long-range forecasting: The practice at the Climate Analysis Center," presented at the CAC Seminar Series, Camp Springs, MD, November 30, 1989.

8.5. GRANT/CONTRACT PROGRAM

CAC continued its support to universities and private industry to undertake diagnostic studies and research that contribute directly to the improvement of CAC's operational monitoring and prediction programs. The results from each project are reported in the literature and in final reports to CAC. Each institution, title of study and principal investigator is listed below.

Start Date	Institution	Title	Principal Investigator
Feb. 1990 (New)	UCLA	Multiple Flow Regimes, Interannual Variability, and Extended-Range Prediction	Ghil
May 1990 (Renewal)	University of Maryland	Cooperative Institute for Climate Studies	Ellingson, et al.
July 1990 (New)	University of Chicago	Statistical Analysis of Stratospheric Temperature Data for Trend Analysis	Tiao

8.6 CAC-SPONSORED SEMINAR SERIES

Speaker: Dr. John Roads
Scripps Institution of Oceanography
La Jolla, California

Title: "Precipitation Forecasts with WMC's MRF Model"

Date: November 15, 1989

Speaker: Prof. Randy Dole
Massachusetts Institute of Technology
Cambridge, Massachusetts

Title: "Variation in Synoptic Scale Eddy Activity During the Life Cycles of Large-Scale Flow Anomalies"

Date: November 16, 1989

Speaker: W. Drosdowsky
Bureau of Meteorology
Melbourne, Australia

Title: "The Southern Oscillation in the Australia Region"

Date: November 21, 1989

Speaker: A. J. Wagner
Prediction Branch/Climate Analysis Center
Camp Springs, Maryland

Title: "Medium and Long-Range Forecasting - The Practice at the Climate Analysis Center"

Date: November 30, 1989

Speaker: Wesley Ebisuzaki
Research and Data Systems, Corp.
Greenbelt, Maryland

Title: "Vertical Tilts of Tropospheric Waves"

Date: December 7, 1989

Speaker: Dr. Arun Kumar
Dept. of Meteorology/Florida State University
Tallahassee, Florida

Title: "Initializing the Divergent Circulations Over the Regions of Convection"

Date: December 18, 1989

Speaker: Ming Cai
Cooperative Institute for Climate Studies/Univ. of MD
College Park, Maryland

Title: "Local Instability, Storm-Tracks and Low-Frequency Variability"

Date January 25, 1990

Speaker: S. P. Leatherman
Center for Global Change/Univ. of MD
College Park, Maryland

Title: "Greenhouse Effect, Sea Level Rise and Coastal Impact"

Date: February 8, 1990

Speaker: Dr. Ian Barrie
U.K. Meteorological Office
Bracknell, Berkshire, U.K.

Title: "Agrometeorological Products in the United Kingdom"

Date: March 1, 1990

Speaker: Dr. J. F. Anderson
Princeton University
Princeton, NJ

Title: "Nearly Stationary Solution of the Barotropic Vorticity Equation"

Date: March 29, 1990

Speaker: Dr. K. R. Saha (Former Director)
Indian Institute of Meteorology
Pune, India

Title: "Understanding Asia's Monsoon Climate System"

Date: April 6, 1990

Speaker: Dr. Edward S. Epstein
Prediction Branch/Climate Analysis Center
Camp Springs, Maryland

Title: "Improving on Perfect Progs!"

Date: April 12, 1990

Speaker: Prof. James L. Kinter
Center for Ocean, Land & Atmosphere/Univ. of MD
College Park, Maryland

Title: "Biophysical Control of Climate: Impact on 30-Day Forecasts"

Date: April 26, 1990

Speaker: Dr. Kingtse Mo
Diagnostics Branch/Climate Analysis Center
Camp Springs, Maryland

Title: "Impact of SST Anomalies on the Skill of Monthly Forecasts"

Date: May 10, 1990

Speaker: Dr. Steven Tracton
Prediction Branch/Climate Analysis Center
Camp Springs, Maryland

Title: "Preliminary Evaluation of CAC's DERF "Spinoff" Experiment (Quasi-Operational Extensions of the MRF to 15 days)"

Date: May 17, 1990

Speaker:	Stanley A Changnon Ill. State Water Survey Champaign, IL	Steve Sonka Univ. of Illinois Champaign, IL
Title:	"Uses and Desires for Long-Term Forecasts in Agribusiness"	
Date:	June 21, 1990	

Speaker: Dr. Ake Johansson
University of Stockholm
Stockholm, Sweden

Title: "Transient-Induced Climate Drift"

Date: June 26, 1990

Speaker: Dr. Huug van den Dool
Prediction Branch/Climate Analysis Center
Camp Springs, MD

Title: "Mirror Images of Atmospheric Flow"

Date: July 12, 1990

Speaker: Dr. Mashida Kimoto
UCLA
Los Angeles, CA

Title: "Diagnostics of the Medium-Range Forecast Skill Variations"

"Multiple Flow Regimes in the Northern Hemisphere Winters"

Date: July 20, 1990

Speaker: A. J. Miller
Anal. & Info. Branch/Climate Analysis Center
Camp Springs, Md

Title: "Monitoring the Stratosphere"

Date: July 26, 1990

Speaker: C. F. Ropelewski
Chief, Diagnotics Branch/Climate Analysis Center
Camp Springs, Md

Title: "Why Predict ENSO?"

Date: August 30, 1990

Speaker: Dr. D. R. Rodenhuis
Director, Climate Analysis Center
Camp Springs, Md

Title: "Where Do We Go From Here? A CAC Perspective on Climate Research and Services"

Date: September 13, 1990

Speaker: Dr. M. Kanamitsu
Development Division/NMC
Camp Springs, Md

Title: "The Use of the Operational Global Prediction Model for Budget Studies"

Date: September 20, 1990

Speaker: Dr. J. F. Anderson
UCAR Post-Doctarate Program
Prediction Branch/Climate Analysis Center
Camp Springs, MD

Title: "Barotropic Instability of Zonally Varying Flows"

Date: September 27, 1990

8.7 VISITORS

NAME	AFFILIATION	DATE
Prof. D. Yihui	Academy of Met. Sciences State Met. Administration Beijing, P.R.C.	Oct. 6, 1989
Prof. C. Longxun	Academy of Met. Sciences State Met. Administration Beijing, P.R.C.	Oct. 6, 1989
Prof. Z. Yunde	Foreign Affairs Dept. State Met. Administration Beijing, P.R.C.	Oct. 6, 1989
Prof. H. Junhai	Nanjing Met. Institute Nanjing, P.R.C.	Oct. 6, 1989
Prof. L. Huibang	Jhongshan University Guangzhou, P.R.C.	Oct. 6, 1989
Prof. H. Shisong	Nanjing University Nanjing, P.R.C.	Oct. 6, 1989
Prof. L. Chongyin	Institute of Atmospheric Physics, CAS Beijing, P.R.C.	Oct. 6, 1989
Prof. Z. Baozhen	Institute of Atmospheric Physics, CAS Beijing, P.R.C.	Oct. 6, 1989
Prof. X. An	Beijing University Beijing, P.R.C.	Oct. 6, 1989
Prof. B. Chenglan	National Research Center for Marine Environmental Forecasting, SOA Beijing, P.R.C.	Oct. 6, 1989
J-H. Feng	Climate Center Meteorological Bureau Shanghai, P.R.C.	Oct. 16, 1989 Sep. 30, 1990
V. T. Radyukhin	World Data Center-B Obninsk, USSR	Oct. 26-30, 1989
G. V. Menzhulin	State Hydrological Inst. Leningrad, USSR	Oct. 26-30, 1989
G. V. Gruza	Hydromet Center of the USSR Moscow, USSR	Oct. 26-30, 1989

G. Farmer	Climate Research Unit East Anglia University Norwich, U.K.	Nov. 8, 1989
W. Drosdowsky	Bureau of Meteorology Research Center - Melbourne Victoria, Australia	Nov. 20-22, 1989
M. Coughlan	National Climate Center Victoria, Australia	Dec. 6, 1989
A. Muhuneh	Commissioner, Ethiopian Science and Technology Commission Adis Ababa, Ethiopia	Jan. 4, 1990
J. Anderson	NOAA/GFDL Princeton, NJ	Jan. 11, 1990
R. Madden	NCAR Boulder, CO	Jan. 12, 1990
S. Goodman	NASA Huntsville, AL	Jan. 23, 1990
P. Sardeshmukh	University of Colorado Boulder, CO	Jan. 23, 1990
J. Henderson	Deputy Director, NWS/Central Region Kansas City, MO	Jan. 25, 1990
R. Ellis	British Met. Office Bracknell, Berkshire U.K.	Feb. 1, 1990
K. Davidson	WMO/WCDP Geneva, Switzerland	Feb. 2, 1990
K. Kutsuwada	University of Tokyo Tokyo, Japan	Feb. 5, 1990
Dr. A. W. Mahottali	Director, Department of Meteorology Sri Lanka	Feb. 8, 1990
Dr. Tatehira	Director, Forecast Dept. Japan Meteor. Agency Tokyo, Japan	Feb. 8, 1990
Dr. D. N. Axford	Deputy Secretary-General WMO Geneva, Switzerland	Feb. 9, 1990

Dr. J-Y. Chang Dr. L-Y. Jen Dr. L-F. Chen Dr. S-S. Chi	Deputy Director-General Assoc. Dir., Forecast Cntr Chief, Forecast Section Dep. Dir., Satellite Cntr Central Weather Bureau Taipai, Taiwan	Feb. 15, 1990
J. NcNitt	NWS/ASOS Program Office Silver Spring, MD	Feb. 28, 1990
Dr. T. Kurino	Research & Development Bureau Science & Technology Agency Tokyo, Japan	Mar. 5, 1990
Dr. Y. Kitamura	Meteor. Research Institute Ibaraki, Japan	Mar. 12, 1990
V. Miller	The Weather Channel Atlanta, GA	Mar. 14, 1990
R. Spencer	NASA Huntsville, AL	Mar. 20, 1990
I. Barrie	British Met. Office Bracknell, Berkshire U.K.	Mar. 21, 1990
M. Roos	California Department of Water Resources Sacramento, CA	Mar. 21, 1990
J. Purvis D. Smith	Southeast Regional Climate Center Columbia, SC	Mar. 24, 1990
Dr. C-Y. Tsay	Director-General, Central Weather Bureau Taipei, Taiwan	Apr. 4, 1990
J-S. Hsieh	Director, Forecast Br. Central Weather Bureau Taipei, Taiwan	Apr. 4, 1990
Dr. J-T. Huang Dr. J-J. Hung Dr. M-S. Sheu Dr. Y-T. Yeh Dr. C-Y. Yen	Dept. of Psychology Dept. of Civil Engr. Dept. of Architecture Dept. of Geology Dept. of Civil Engr. National Taiwan University Taipei, Taiwan	Apr. 4, 1990
M. Harrison	British Met. Office Bracknell, Berkshire U.K.	May 29, 1990

N. Cutler	Executive Director, Canadian Climate Centre Downsview, Canada	June 18, 1990
Dr. I. Mokhov	Inst. for Atmos. Physics USSR Academy of Sciences Moscow, USSR	June 27, 1990
B. Rudolf H. Hauschild	German Weather Service Offenbach, FRG	June 28, 1990
John Bates	NOAA/ERL Boulder, CO	July 3, 1990
A. Kassar	Deputy Director, Economic Meteorology Nat'l. Inst. of Meteorology Tunis, Tunisia	July 6, 1990
Prof. K. Kondratoveich	Hydrometeorological Training Institute Leningrad, USSR	July 19, 1990
M. Kimoto	Dept. of Atmospheric Sciences UCLA Los Angeles, CA	July 20, 1990
Dr. J. A. Knauss	Under Secretary of Commerce for Oceans and Atmosphere Washington, D.C.	July 25, 1990
Dr. N. Ostenso	Assistant Administrator, Office of Research, NOAA Rockville, MD	July 25, 1990
I. Matos	Meteorologist-In-Charge, NWS L.M.M. International Airport San Juan, Puerto Rico	Aug. 30, 1990
Dr. R. H. Reitenbach	Director All-Union Research Inst. of Hydrometeor. Info. Obninsk, USSR	Sept. 17, 1990
Dr. A. Sterin	Head, Aerology Dept. All-Union Research Inst. of Hydrometeor. Info. Obninsk, USSR	Sept. 17, 1990