NOAA TECHNICAL MEMORANDUM
NWS WR-245

CLIMATOLOGY OF CAPE FOR EASTERN MONTANA AND NORTHERN WYOMING

Heath Hockenberry
Keith Meier
NEXRAD Weather Service Office
Billings, Montana

January 1997

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

NOAA TECHNICAL MEMORANDA
National Weather Service, Western Region Subseries

The National Weather Service (NWS) Western Region (WR) Subseries provides an informal medium for the documentation and quick dissemination of results not appropriate, or not yet ready, for formal publication. The series is used to report on work in progress, to describe technical procedures and practices, or to relate progress to a limited audience. These Technical Memoranda will report on investigations devoted primarily to regional and local problems of interest mainly to personnel, and hence will not be widely distributed.

Papers 1 to 25 are in the former series, ESSA Technical Memoranda, Western Region Technical Memoranda (WRTM); papers 24 to 59 are in the former series, ESSA Technical Memoranda, Weather Bureau Technical Memoranda (WBTM). Beginning with 60, the papers are part of the series, NOAA Technical Memoranda NWS. Out-of-print memoranda are not listed.

Papers 2 to 22, except for 5 (revised edition), are available from the National Weather Service Western Region, Scientific Services Division, 125 South State Street - Rm 1210, Salt Lake City, Utah 84138-1102. Paper 5 (revised edition), and all others beginning with 25 are available from the National Technical Information Service, U.S. Department of Commerce, Sills Building, 5285 Port Royal Road, Springfield, Virginia 22161. Prices vary for all paper copies; microfiche are $3.50. Order by accession number shown in parentheses at end of each entry.

ESSA Technical Memoranda (WRTM)

2 Climatological Precipitation Probabilities. Compiled by Lucianne Miller, December 1965.
3 Western Region Pre- and Post-FP-3 Program, December 1, 1965, to February 20, 1966. Edward D. Diemer, March 1966.
5 Station Descriptions of Local Effects on Synoptic Weather Patterns. Philip Williams, Jr., April 1966 (Revised November 1967, October 1969). (PB-17800)
8 Interpreting the RAREP. Herbert P. Benner, May 1966 (Revised January 1967).
11 Some Electrical Processes in the Atmosphere. J. Latham, June 1966.
17 A Digitalized Summary of Radar Echoes within 100 Miles of Sacramento, California. J. A. Youngberg and L. B. Overaas, December 1966.
21 An Objective Aid for Forecasting the End of East Winds in the Columbia Gorge, July through October. D. John Coparanis, April 1967.
22 Derivation of Radar Horizons in Mountainous Terrain. Roger G. Pappas, April 1967.

ESSA Technical Memoranda, Weather Bureau Technical Memoranda (WBTM)

25 Verification of Operation Probability of Precipitation Forecasts, April 1966-March 1967. W. W. Dickey, October 1967. (PB-176240)
26 A Study of Winds in the Lake Mead Recreation Area. R. P. Augulis, January 1968. (PB-177830)
28 Weather Extremes. R. J. Schmidli, April 1968 (Revised March 1986). (PB86 177672/AS). (Revised October 1991 - PB92-115062/AS)
29 Small-Scale Analysis and Prediction. Philip Williams, Jr., May 1968. (PB178425)
30 Numerical Weather Prediction and Synoptic Meteorology. CPT Thomas D. Murphy, USAF, May 1968 (AD 673365)
31 Precipitation Detection Probabilities by Salt Lake ARTC Radars. Robert K. Belesky, July 1968. (PB 179084)
32 Probability Forecasting--A Problem Analysis with Reference to the Portland Fire Weather District. Harold S. Ayer, July 1968. (PB 179289)
36 Temperature Trends in Sacramento--Another Heat Island. Anthony D. Lentini, February 1969. (PB 183055)
37 Disposal of Logging Residues Without Damage to Air Quality. Owen P. Cramer, March 1969. (PB 183057)
39 Upper-Air Lows Over Northwestern United States. A.L. Jacobson, April 1969. PB 184296)
40 The Man-Machine Mix in Applied Weather Forecasting in the 1970s. L.W. Snellman, August 1969. (PB 185068)
43 Forecasting Maximum Temperatures at Helena, Montana. David E. Olsen, October 1969. (PB 185762)
44 Estimated Return Periods for Short-Duration Precipitation in Arizona. Paul C. Kangieser, October 1969 (PB 187763)
46 Applications of the Net Radiometer to Short-Range Fog and Stratus Forecasting at Eugene, Oregon. L. Yee and E. Bates, December 1969. (PB 190476)
47 Statistical Analysis as a Flood Routing Tool. Robert J.C. Burnash, December 1969. (PB 188744)
48 Tsunami. Richard P. Augulis, February 1970. (PB 190157)
49 Predicting Precipitation Type. Robert J.C. Burnash and Floyd E. Hug, March 1970. (PB 190962)
50 Statistical Report on Aeroallergens (Pollens and Molds) Fort Huachuca, Arizona, 1969. Wayne S. Johnson, April 1970. (PB 191743)
51 Western Region Sea State and Surf Forecaster's Manual. Gordon C. Shields and Gerald B. Burdwell, July 1970. (PB 193102)
52 Sacramento Weather Radar Climatology. R.G. Pappas and C. M. Veliquette, July 1970. (PB 193347)
54 A Refinement of the Vorticity Field to Delineate Areas of Significant Precipitation. Barry B. Aronovitch, August 1970.
55 Application of the SSARR Model to a Basin without Discharge Record. Vail Schermerhorn and Donal W. Kuehl, August 1970. (PB 194394)
56 Areal Coverage of Precipitation in Northwestern Utah. Philip Williams, Jr., and Werner J. Heck, September 1970. (PB 194389)
57 Preliminary Report on Agricultural Field Burning vs. Atmospheric Visibility in the Willamette Valley of Oregon. Earl M. Bates and David O. Chilcote, September 1970. (PB 194710)
58 Air Pollution by Jet Aircraft at Seattle-Tacoma Airport. Wallace R. Donaldson, October 1970. (COM 71 00017)
59 Application of PE Model Forecast Parameters to Local-Area Forecasting. Leonard W. Snellman, October 1970. (COM 71 00016)
60 An Aid for Forecasting the Minimum Temperature at Medford, Oregon, Arthur W. Fritz, October 1970. (COM 71 00120)
63 700-mb Warm Air Advection as a Forecasting Tool for Montana and Northern Idaho. Norris E. Woerner, February 1971. (COM 71 00349)
64 Wind and Weather Regimes at Great Falls, Montana. Warren B. Price, March 1971.
65 Climate of Sacramento, California. Richard Honton and Tony Martini (Retired), August 1996. (Fifth Revision) (PB89 207781/AS)
66 A Preliminary Report on Correlation of ARTCC Radar Echoes and Precipitation. Wilbur K. Hall, June 1971. (COM 71 00829)
69 National Weather Service Support to Soaring Activities. Ellis Burton, August 1971. (COM 71 00956)
71 Western Region Synoptic Analysis-Problems and Methods. Philip Williams, Jr., February 1972. (COM 72 10433)
74 Thunderstorms and Hail Days Probabilities in Nevada. Clarence M. Sakamoto, April 1972. (COM 72 10554)
75 A Study of the Low Level Jet Stream of the San Joaquin Valley. Ronald A. Willis and Philip Williams, Jr., May 1972. (COM 72 10707)
76 Monthly Climatological Charts of the Behavior of Fog and Low Stratus at Los Angeles International Airport. Donald M. Gales, July 1972. (COM 72 11140)
77 A Study of Radar Echo Distribution in Arizona During July and August. John E. Hales, Jr., July 1972. (COM 72 11136)
78 Forecasting Precipitation at Bakersfield, California, Using Pressure Gradient Vectors. Earl T. Riddiough, July 1972. (COM 72 11146)
79 Climate of Stockton, California. Robert C. Nelson, July 1972. (COM 72 10920)
80 Estimation of Number of Days Above or Below Selected Temperatures. Clarence M. Sa October 1972. (COM 72 10021)
81 An Aid for Forecasting Summer Maximum Temperatures at Seattle, Washington. Edgar G. Johnson, November 1972. (COM 73 10150)
82 Flash Flood Forecasting and Warning Program in the Western Region. Philip Williams, Jr., Chester L. Glenn, and Roland L. Raetz, December 1972, (Revised March 1978). (COM 73 10251)
83 A comparison of Manual and Semiautomatic Methods of Digitizing Analog Wind Records. Glenn E. Rasch, March 1973. (COM 73 10669)
86 Conditional Probabilities for Sequences of Wet Days at Phoenix, Arizona. Paul C. Kangieser, June 1973. (COM 73 11264)
87 A Refinement of the Use of K-Values in Forecasting Thunderstorms in Washington and Oregon. Robert Y.G. Lee, June 1973. (COM 73 11276)
89 Objective Forecast Precipitation Over the Western Region of the United States. Julia N. Paegle and Larry P. Kierulff, September 1973. (COM 73 11946/3AS)
91 Arizona "Eddy" Tornadoes. Robert S. Ingram, October 1973. (COM 73 10465)
92 Smoke Management in the Willamette Valley. Earl M. Bates, May 1974. (COM 74 11277/AS)
93 An Operational Evaluation of 500-mb Type Regression Equations. Alexander E. MacDonald, June 1974. (COM 74 11407/AS)
94 Conditional Probability of Visibility Less than One-Half Mile in Radiation Fog at Fresno, California. John D. Thomas, August 1974. (COM 74 11555/AS)
95 Climate of Flagstaff, Arizona. Paul W. Sorenson, and updated by Reginald W. Preston, January 1987. (PB87 143160/AS)
96 Map type Precipitation Probabilities for the Western Region. Glenn E. Rasch and Alexander E. MacDonald, February 1975. (COM 75 10428/AS)
97 Eastern Pacific Cut-Off Low of April 21-28, 1974. William J. Alder and George R. Miller, January 1976. (PB 250 711/AS)
98 Study on a Significant Precipitation Episode in Western United States. Ira S. Brenner, April 1976. (COM 75 10719/AS)
99 A Study of Flash Flood Susceptibility-A Basin in Southern Arizona. Gerald Williams, August 1975. (COM 75 11360/AS)
102 A Set of Rules for Forecasting Temperatures in Napa and Sonoma Counties. Wesley L. Tuft, October 1975. (PB 246 902/AS)
103 Application of the National Weather Service Flash-Flood Program in the Western Region. Gerald Williams, January 1976. (PB 253 053/AS)
104 Objective Aids for Forecasting Minimum Temperatures at Reno, Nevada, During the Summer Months. Christopher D. Hill, January 1976. (PB 252 866/AS)
105 Forecasting the Mono Wind. Charles P. Ruscha, Jr., February 1976. (PB 254 650)
106 Use of MOS Forecast Parameters in Temperature Forecasting. John C. Plankinton, Jr., March 1976. (PB 254 649)
107 Map Types as Aids in Using MOS PoPs in Western United States. Ira S. Brenner, August 1976. (PB 259 594)
108 Other Kinds of Wind Shear. Christopher D. Hill, August 1976. (PB 260 437/AS)
109 Forecasting North Winds in the Upper Sacramento Valley and Adjoining Forests. Christopher E. Fontana, September 1976. (PB 273 677/AS)
110 Cool Inflow as a Weakening Influence on Eastern Pacific Tropical Cyclones. William J. D November 1976. (PB 264 655/AS)
112 The MAN/MOS Program. Alexander E. MacDonald, February 1977. (PB 265 941/AS)
113 Winter Season Minimum Temperature Formula for Bakersfield, California, Using Multiple Regression. Michael J. Oard, February 1977. (PB 273 694/AS)
114 Tropical Cyclone Kathleen. James R. Fors, February 1977. (PB 273 676/AS)
116 A Study of Wind Gusts on Lake Mead. Bradley Colman, April 1977. (PB 268 847)
117 The Relative Frequency of Cumulonimbus Clouds at the Nevada Test Site as a Function of K-Value. R.F. Quiring, April 1977. (PB 272 831)
118 Moisture Distribution Modification by Upward Vertical Motion. Ira S. Brenner, April 1977. (PB 268 740)
119 Relative Frequency of Occurrence of Warm Season Echo Activity as a Function of Stability Indices Computed from the Yucca Flat, Nevada, Rawinsonde. Darryl Randerson, June 1977. (PB 271 290/AS)
121 Climatological Prediction of Cumulonimbus Clouds in the Vicinity of the Yucca Flat Weather Station. R.F. Quiring, June 1977. (PB 271 704/AS)
122 A Method for Transforming Temperature Distribution to Normality. Morris S. Webb, Jr., June 1977. (PB 271 742/AS)
124 Statistical Guidance for Prediction of Eastern North Pacific Tropical Cyclone Motion - Part I. Charles J. Neumann and Preston W. Leftwich, August 1977. (PB 272 661)
125 Statistical Guidance on the Prediction of Eastern North Pacific Tropical Cyclone Motion - Part II. Preston W. Leftwich and Charles J. Neumann, August 1977. (PB 273 155/AS)
126 Climate of San Francisco. E. Jan Null, February 1978. (Revised by George T. Pericht, April 1988 and January 1995). (PB88 208624/AS)
127 Development of a Probability Equation for Winter-Type Precipitation Patterns in Great Falls, Montana. Kenneth B. Mielke, February 1978. (PB 281 387/AS)
128 Hand Calculator Program to Compute Parcel Thermal Dynamics. Dan Gudgel, April 1978. (PB 283 080/AS)
129 Fire whirls. David W. Goens, May 1978. (PB 283 866/AS)
130 Flash-Flood Procedure. Ralph C. Hatch and Gerald Williams, May 1978. (PB 286 014/AS)
131 Automated Fire-Weather Forecasts. Mark A. Mollner and David E. Olsen, September 1978. (PB 289 916/AS)
132 Estimates of the Effects of Terrain Blocking on the Los Angeles WSR-74C Weather Radar. R.G. Pappas, R.Y. Lee, B.W. Finke, October 1978. (PB 289767/AS)
133 Spectral Techniques in Ocean Wave Forecasting. John A. Jannuzzi, October 1978. (PB291317/AS)
134 Solar Radiation. John A. Jannuzzi, November 1978. (PB291195/AS)
135 Application of a Spectrum Analyzer in Forecasting Ocean Swell in Southern California Coastal Waters. Lawrence P. Kierulff, January 1979. (PB292716/AS)
136 Basic Hydrologic Principles. Thomas L. Dietrich, January 1979. (PB292247/AS)
137 LFM 24-Hour Prediction of Eastern Pacific Cyclones Refined by Satellite Images. John R. Zimmerman and Charles P. Ruscha, Jr., January 1979. (PB294324/AS)
138 A Simple Analysis/Diagnosis System for Real Time Evaluation of Vertical Motion. Scott Heflick James R. Fors, February 1979. (PB294216/AS)
139 Aids for Forecasting Minimum Temperature in the Wenatchee Frost District. Robert S. Robi April 1979. (PB298339/AS)
140 Influence of Cloudiness on Summertime Temperatures in the Eastern Washington Fire Weather district. James Holcomb, April 1979. (PB298674/AS)
141 Comparison of LFM and MFM Precipitation Guidance for Nevada During Doreen. Christopher Hill, April 1979. (PB298613/AS)
142 The Usefulness of Data from Mountaintop Fire Lookout Stations in Determining Atmospheric Stability. Jonathan W. Corey, April 1979. (PB298899/AS)
143 The Depth of the Marine Layer at San Diego as Related to Subsequent Cool Season Precipitation Episodes in Arizona. Ira S. Brenner, May 1979. (PB298817/AS)

NOAA TECHNICAL MEMORANDUM
NWS WR-245

CLIMATOLOGY OF CAPE FOR EASTERN MONTANA AND NORTHERN WYOMING

Heath Hockenberry
Keith Meier
NEXRAD Weather Service Office
Billings, Montana

January 1997

UNITED STATES
DEPARTMENT OF COMMERCE
William Daley, Secretary

National Oceanic and
Atmospheric Administration
D. James Baker, Under
Secretary and Administrator

National Weather Service
Elbert W. Friday, Jr., Assistant
Administrator for Weather Services

This publication has been reviewed and is approved for publication by Scientific Services Division, Western Region

Delain A. Edman, Chief
Scientific Services Division
Salt Lake City, Utah

TABLE OF CONTENTS

List of Figures

List of Tables

CLIMATOLOGY OF CAPE FOR EASTERN MONTANA AND NORTHERN WYOMING

Heath Hockenberry and Keith Meier
Nexrad Weather Service Office
Billings, Montana

Development of a warm season climatology of Convective Available Potential Energy (CAPE) for the Northern Plains Region of eastern Montana and northern Wyoming provides forecasters with typical convective energy values. These typical CAPE values may be used to isolate standard and anomalous convective potential, both monthly and seasonally. To derive the CAPE averages, daily values of 0000 UTC and 1200 UTC CAPE from April through September during the 1961-1991 time period were analyzed using the SHARP Workstation and the statistical applications inherent in Quattro Pro. The averages and statistics show that July is the month for the greatest CAPE values with a 31 year average of 470 J kg^{-1}. In addition, seasonal average CAPE values isolate 1962, 1963,1982, and 1991 as those years having the greatest seasonal averages. Finally, the CAPE averages show that maximum daily CAPE values rarely exceed 1000 J kg^{-1} during most of the warm season.

I. Introduction

Convective Available Potential Energy (CAPE) is an important parameter in the production of severe weather. Its influences, in combination with vertical wind shear, drive sustained convection. In the Northern Plains area of eastern Montana and northern Wyoming, CAPE values and averages are somewhat enigmatic due to a lack of climatology for the important severe weather contributor. This study attempts to provide basic quantification of eastern Montana and northern Wyoming (Northern Plains) values and establishes a 31 year climatology of CAPE from 1961 through 1991 during the warm season. Average CAPE values are broken down by year, month, and location with useful statistics which correspond to each graph. In addition, maximum daily CAPE for each site and month are divided into CAPE ranges which are directly given cumulative percentages. The cumulative percentages illustrate the frequency of occurrence of a maximum afternoon CAPE at a specific time of year and location. This study intends to establish a CAPE climatology for the plains of eastern Montana and northern Wyoming, provide a guide of typical CAPE values and the relative frequency of maximum CAPE values over a 31 year period, illustrate statistical measurements of CAPE, and serve as a platform for future individual case studies of severe weather episodes.

II. Procedure

The data used to calculate the Convective Available Potential Energy values in this study were collected using North American RAOB data and the SHARP Workstation program (*Hart and Korotky, 1991*). The upper-air mandatory and significant level data for the warm season (April through September) from Great Falls, Glasgow, Lander, and Rapid City from 1961 through 1991 were copied to a disk from the CD-ROM of Radiosonde Data which was produced by the Forecast Systems Lab and the National Climatic Data Center. These mandatory and significant level files were then imported into the SHARP Workstation. Using SHARP's Database option, the default CAPE values for each sounding, both the 0000 UTC and 1200 UTC runs, were calculated and copied to a disk. SHARP calculates these default CAPE values using the most unstable parcel in the lowest 150 mb of the sounding. The data-based CAPE values were then imported into Quattro Pro for final analysis and graph generation. These were then built into a comprehensive database for forecasting reference and any future studies.

The quality control measures taken during the data collection included ranking all the CAPE from largest to smallest and individually screening those soundings which produced CAPE values greater than 6000 J kg^{-1} (a climatologically high value for the Northern Plains). Those soundings which appeared to be erroneous, perhaps because of bad balloon release, were deleted and not included in the final results. However, the overall intention of this part of the study was to be as objective as possible in the collection of the data. Only those CAPE values which were obviously too large were deleted.

III. Analysis and Observations

Figure 1 represents the seasonal CAPE averages for all sites and at both 0000 UTC and 1200 UTC during the period 1961-1991. The relative peak years for Northern Plains CAPE average were 1963, 1972, 1976, 1983, and 1991. The intervals between these years ranged between four and nine years. Table 1.a and 1.b, (See Appendix A for definitions of statistical parameters), shows that the maximum seasonal value during the 31 year period occurred in 1963 with an overall average CAPE value of 368.66 J kg^{-1} and the minimum occurred in 1971 with a CAPE of 194.83 J kg^{-1}. The range of 173.83 J kg^{-1} between the highest and lowest values along with the relatively low value of standard deviation shows the homogenous nature of the Northern Plains warm season CAPE values from year to year.

Sub-dividing the seasonal average CAPE values into its individual site components illustrates each site's average seasonal CAPE value from 1961 to 1991 (Figs 2.a-d) and shows the corresponding descriptive statistics for each site's 31 yearly averages (Table 2). Comparison of these graphs clearly shows that Rapid City generally yields higher seasonal CAPE averages than any of the other three locations. The year of 1963 resulted in seasonal average spikes in Glasgow, Lander, and Rapid City. Both

Glasgow and Rapid City show a maximum in 1983. During the rest of the years, each station shows average spikes in different years with little correlation between locations.

Table 2 illustrates that Great Falls has the highest central tendency with Rapid City showing greater variability. As many of the statistics show, Rapid City once again has the highest absolute values of CAPE with Great Falls showing the lowest numbers. This is most likely the result of the Gulf of Mexico moisture influence on Rapid City's boundary layer moisture profile while Great Falls lies in a downsloping and typically drier area.

In addition, CAPE values may be broken down by month for each upper-air site to represent the average of the 0000 UTC and 1200 UTC averages for the years of 1961 through 1991 (Figs 3.a-d). All the graphs show maximum values in July with June coming in second. The figures also illustrate dramatic CAPE average drops from August to September. Table 3 is the corresponding statistical breakdown of the 0000 UTC and 1200 UTC combination average for each site by month. Low averages and small standard deviations for each location clearly show that April and September are the least favorable months for deep convection.

Consolidating the individual site data for each month illustrates an average of the 0000 UTC and 1200 UTC values from 1961 to 1991 for all four upper-air locations used in this study (Figs 4.a-f). These then are stratified by month. Table 4 is the standard statistics for all of the 248 included values for the Northern Plains warm season.

Little variation in yearly seasonal CAPE can be noted in April. May brings a general doubling of average seasonal values with maxima occurring in 1977 and 1991. During the transition from May to June, there is a dramatic jump in seasonal CAPE values. July displays the highest overall values along with the greatest variability from year to year with a standard deviation of 383 J kg^{-1}. August becomes more homogenous with an obvious seasonal average spike during 1983. Finally, September returns to April-like averages while still retaining a lower central tendency than the values from April.

The groups of figures from 5.a to 10.d show the cumulative percentages of all the collected CAPE values from 1961 to 1991 versus 50 J kg^{-1} CAPE bins for each month and station. The charts keep a running percentage of exactly which percentage of CAPE values fall below the value displayed along the y-axis. Tables 5 through 10 show the corresponding statistics for each station's CAPE values, broken down by month. All the values were analyzed at 0000 UTC, which was used to represent the maximum CAPE values of the day.

The charts give useful information about those CAPE values which are anomalously high during a given month as well as general information on the frequency of particular CAPE values.

Comparing cumulative percentages illustrates the amount of observations during a 31 year period which fell above and below a certain CAPE value. For example, using figures 5.a through 10.d, April contains CAPE values which are mostly in the 0 to 200 J kg^{-1} category. About 75 percent of all the values at 0000 UTC collected for each site fall below 200 J kg^{-1} in April. But in May, 75 percent fall below 400 J kg^{-1}, a generally doubling of values. In June and July, 75 percent of the collected CAPE values exist in the 0 to 1550 J kg^{-1} area. All of the charts together show that the majority of all CAPE values for any station at any time of the warm season fall within the 0 to 800 J kg^{-1} group.

In addition, the figures illustrate the extreme small percentage of those CAPE values which come close to those which are considered as being "high" over the Central Plains. For example, in Rapid City only five percent of 919 cases over the past 31 years have resulted in CAPE values which are greater than 3,000 J kg^{-1} at 0000 UTC.

Tables 5 through 10 give descriptive statistics of the individual data points used in generating Figures 5.a to 10.d. A very useful statistical theorem may be applied using the numbers in these charts. The theorem gives information on the percentage of values which should fall between a certain number of standard deviations above and below a mean, using any shape of frequency distribution. The following equation illustrates Chebeyshev's Theorem (Twark 1991):

$$P(\mu - k\sigma < \mu < \mu + k\sigma) = 1(k^2)^{-1}$$

where P is Probability, μ is the sample mean, k is an arbitrary constant, and σ is the sample standard deviation.

This means that 75 percent of all values of a population of numbers should fall between plus or minus two standard deviations from the mean and 89 percent of all values should be expected to fall between plus or minus three standard deviations from the mean. For example, Table 8 shows the 0000 UTC statistics for July in Rapid City. According to Chebeyshev's Theorem, 75 percent of all values from the population of values at 0000 UTC in July in Rapid City should range between 3130 J kg^{-1} and -962 J kg^{-1}. (The -962 J^{1} kg CAPE value is unrealistic, but the theorem still holds). This illustrates the rarity of finding CAPE greater than 3138 J kg^{-1} in Rapid City during the evening in July.

IV. Conclusions and Future Possibilities.

During the years from 1961 through 1991, seasonal CAPE averages for the warm season in eastern Montana and northern Wyoming have generally varied between 299 J kg^{-1} and 218 J kg^{-1}. The only yearly averages which have exceeded the maximum of this range have been in 1962, 1963, 1983, and 1991. The synoptic and mesoscale reasons for these yearly peaks are beyond the scope of this study. However, this study has provided information on those years which could be studied in more detail.

Yearly averages at individual sites indicate that Rapid City has twice as much CAPE during most years than

Glasgow, Great Falls, and Lander. This doubling occurs during June, July and August as illustrated by Table 3. The table shows the results from further subdividing the data into individual monthly averages from 1961-1991.

Finally, Fig. 5 -10 illustrate those months with the least and most deep convection potential. From April through May and August through September, which includes 14,903 soundings, 72 percent or greater of all the maximum afternoon CAPE values have been below 1000 J kg^{-1}. According to Bluestein, most moderate to strong convection occurs when CAPE values are greater than 1000 J kg^{-1} (Bluestein 1993), This would lead to the conclusion that most severe weather in eastern Montana and northern Wyoming occurs in July. However, future studies will have to verify this.

Follow-up work is clearly necessary to explain why CAPE averages exist as they do in the Northern Plains region of eastern Montana and northern Wyoming. This study provides the background information necessary to isolate the years and months in which the CAPE averages and values were in the range where moderate to strong convection did or may have occurred. The CAPE values used in this study could then be stratified based on reports of severe versus non-severe weather during those periods of anomalously high convective potential. This may prove to be a valuable learning tool for the prediction of severe weather in eastern Montana and northern Wyoming, especially for anomalous events of severe weather.

V. References

Bluestein, H.B., 1993: *Synoptic-Dynamic Meteorology in Midlatitudes: Volume II - Observations and Theory of Weather Systems.* Oxford University Press, Inc. 594 pp.

Hart, J.A. and J. Korotky, 1991: The SHARP Workstation-a Skew-T/Hodograph analysis and research program. NOAA/NWS NWSFO Charleston.

Panofsky, H.A. and Brier, G.W., 1958: *Some Applications of Statistics to Meteorology.* The Pennsylvania State University Press, University Park, Pa. 224 pp.

Twark, Richard, 1991: *Quantitative Business Analysis 200.4 & .5.* The Pennsylvania State University Press, University Park, PA. 140 pp.

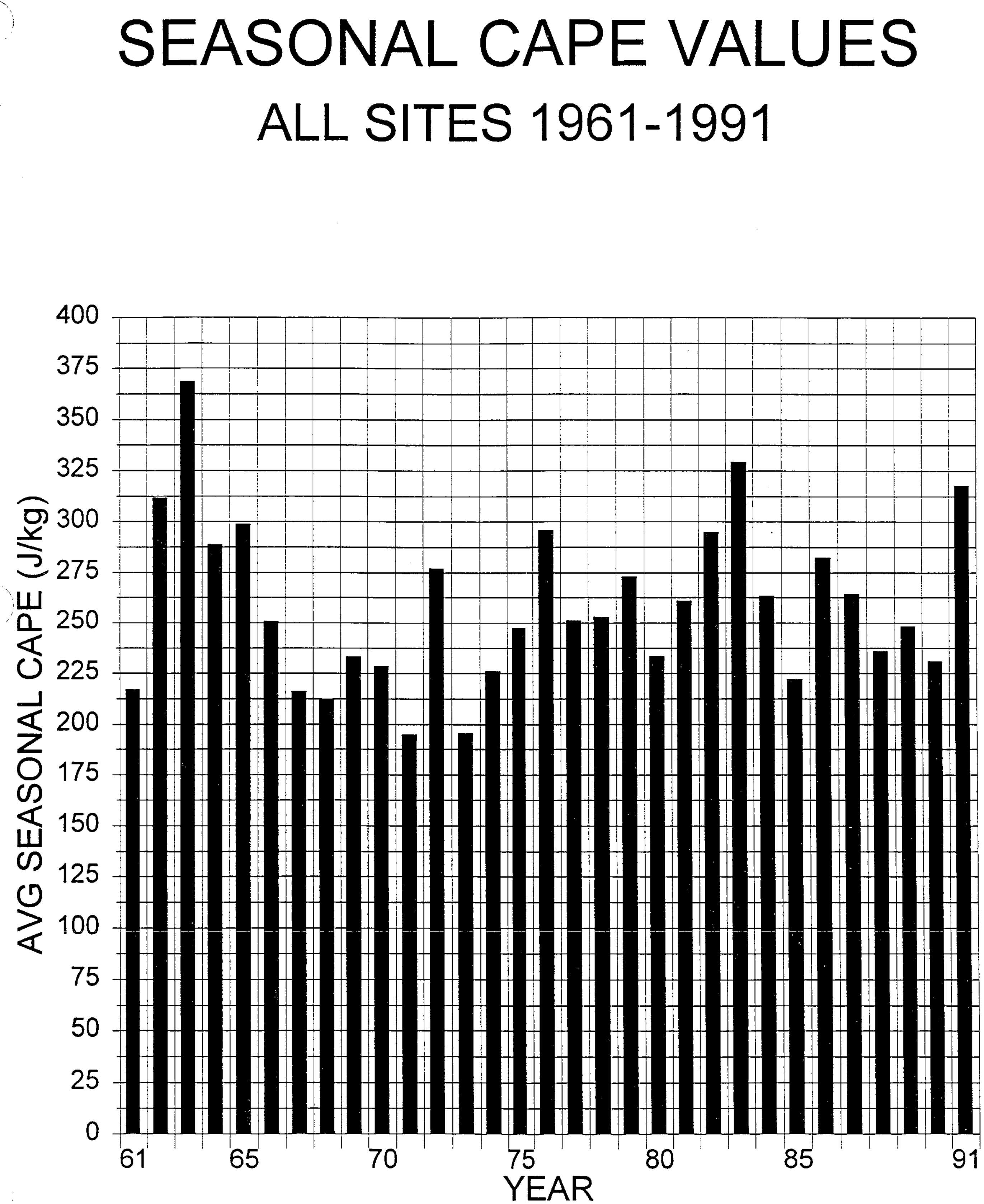

SEASONAL CAPE VALUES
ALL SITES 1961-1991
AVG SEASONAL CAPE (J/kg)
400
375
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
61
65
70
75
80
85
91
YEAR

Fig. 1

YEAR	CAPE
1961	217.31
1962	311.6
1963	368.66
1964	288.64
1965	298.68
1966	250.91
1967	216.28
1968	212.46
1969	233.3
1970	228.47
1971	194.83
1972	277.04
1973	195.47
1974	225.87
1975	247.41
1976	295.94
1977	251.17
1978	253.13
1979	272.98
1980	233.54
1981	260.98
1982	294.92
1983	329.44
1984	263.56
1985	222.19
1986	282.32
1987	264.38
1988	236.22
1989	247.95
1990	230.92
1991	317.58

Table 1.a

SEASONAL CAPE (ALL SITES)

Column 1	
Mean	258.84355
Median	251.17
Mode	NA
Standard Deviation	40.707175
Variance	1657.0741
Kurtosis	0.3329717
Skewness	0.6797226
Range	173.83
Minimum	194.83
Maximum	368.66
Sum	8024.15
Count	31
Confidence Level(0.950000)	14.329737

Table 1.b

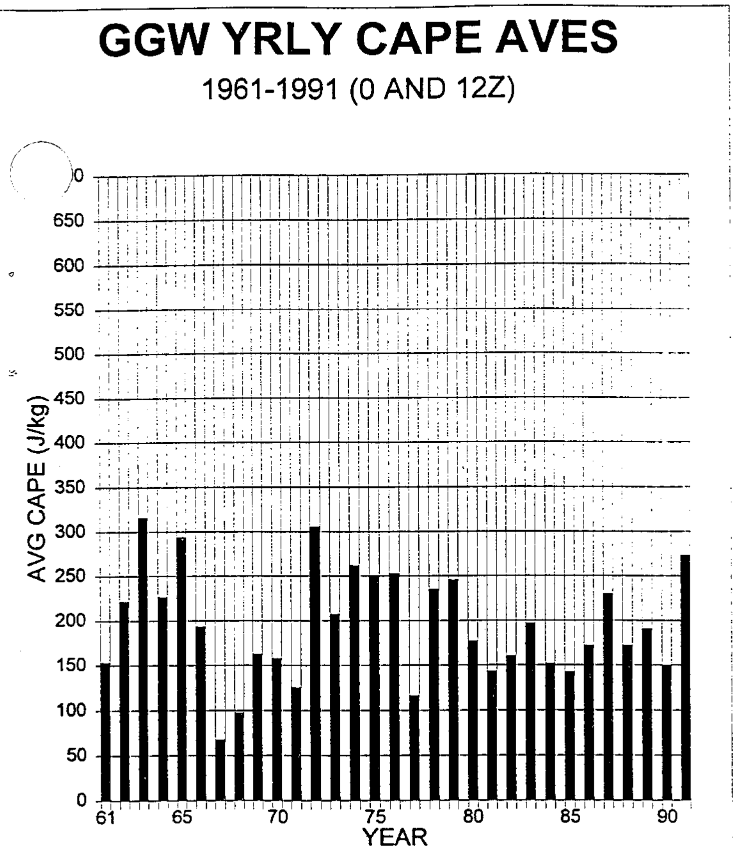


Fig 2.a

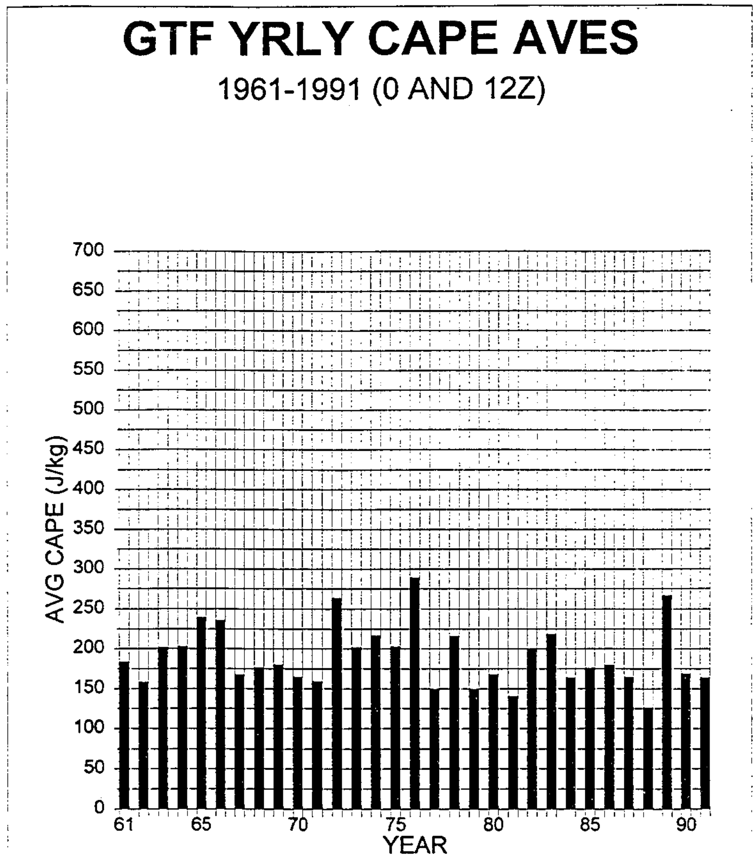


Fig 2.b

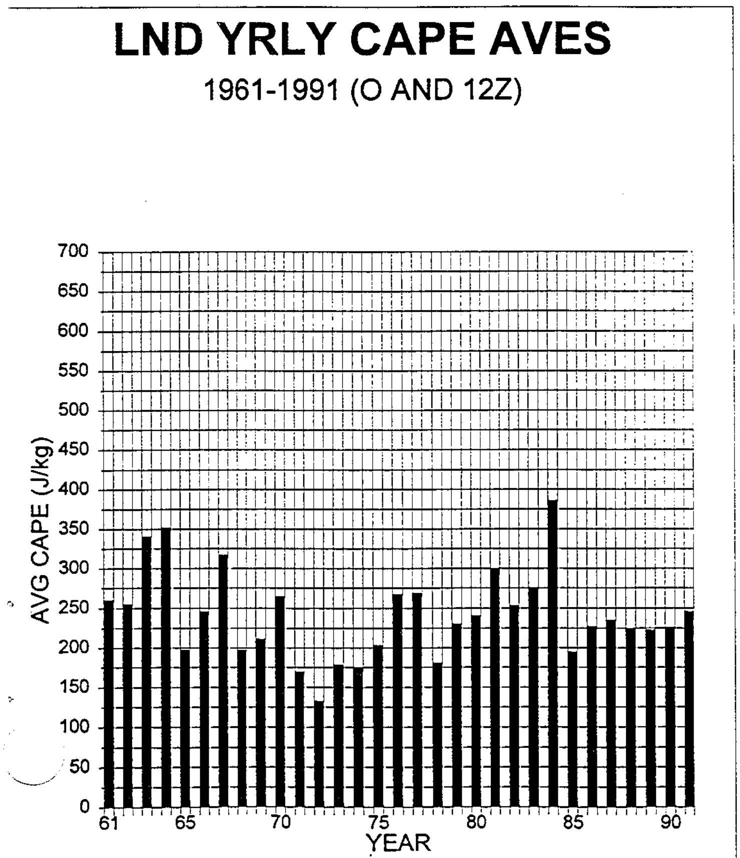


Fig 2.c

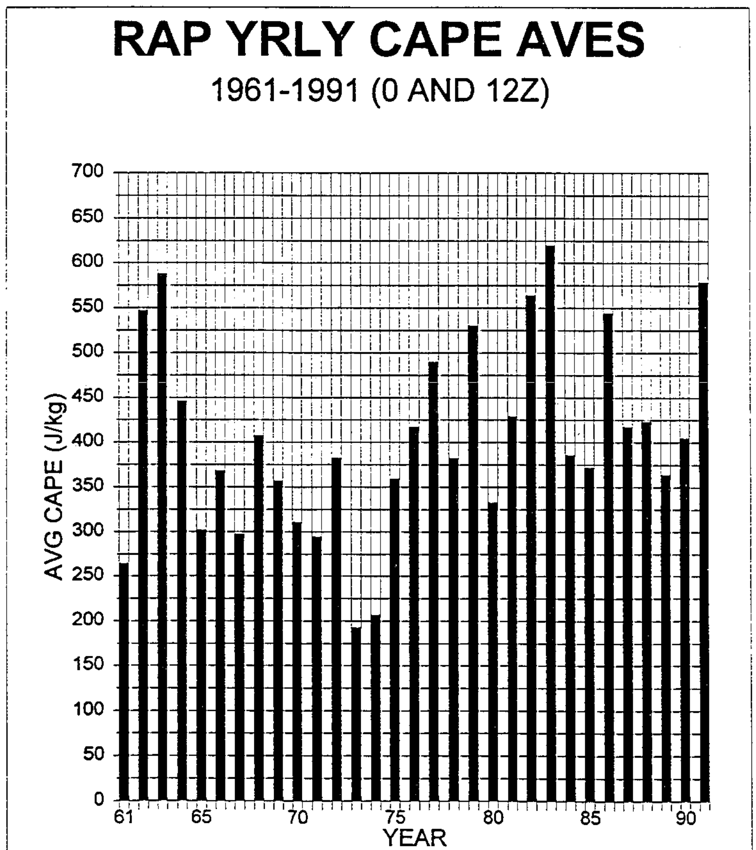


Fig 2.d

GGW YRLY CAPE AVES

Column 1	
Mean	195.34
Median	190.88
Mode	0
Standard Deviation	61.55
Variance	3788.5
Kurtosis	-1.348
Skewness	0.439
Range	248.35
Minimum	67.354
Maximum	315.68
Sum	6055.7
Count	31
Confidence Level(0.950000)	21.667

GTF YRLY CAPE AVES

Column 1	
Mean	190.38
Median	179.59
Mode	0
Standard Deviation	38.742
Variance	1501
Kurtosis	-1.65
Skewness	0.2138
Range	163.2
Minimum	126.36
Maximum	289.55
Sum	5901.7
Count	31
Confidence Level(0.950000)	13.638

LND YRLY CAPE AVES

Column 1	
Mean	241.31
Median	235.1
Mode	0
Standard Deviation	56.023
Variance	3138.6
Kurtosis	-1.546
Skewness	0.2742
Range	252.2
Minimum	133.26
Maximum	385.46
Sum	7480.7
Count	31
Confidence Level(0.950000)	19.721

RAP YRLY CAPE AVES

Column 1	
Mean	405.72
Median	385.37
Mode	0
Standard Deviation	110.11
Variance	12125
Kurtosis	-1.498
Skewness	0.3426
Range	426.8
Minimum	192.81
Maximum	619.57
Sum	12577
Count	31
Confidence Level(0.950000)	38.762

Table 2

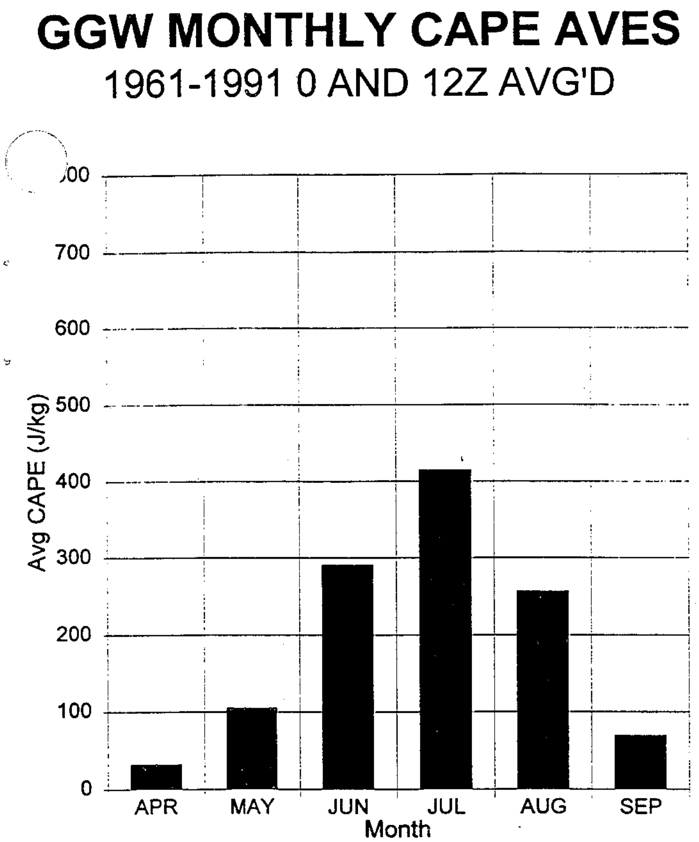


Fig 3.a

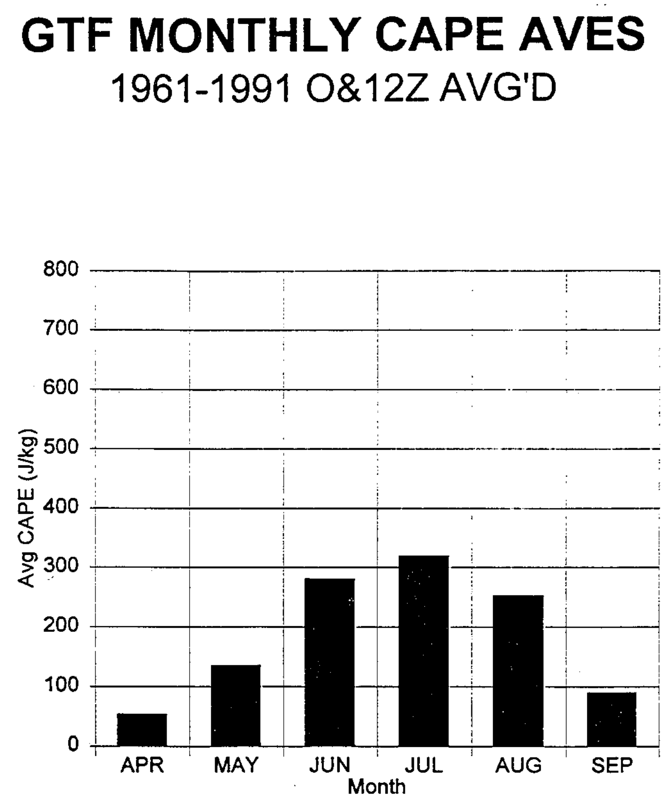


Fig 3.b

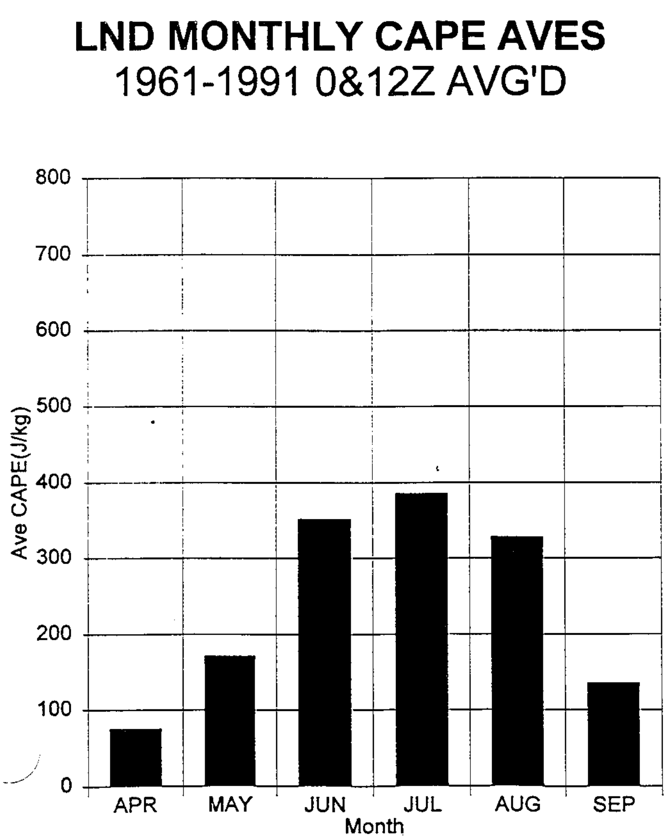


Fig 3.c

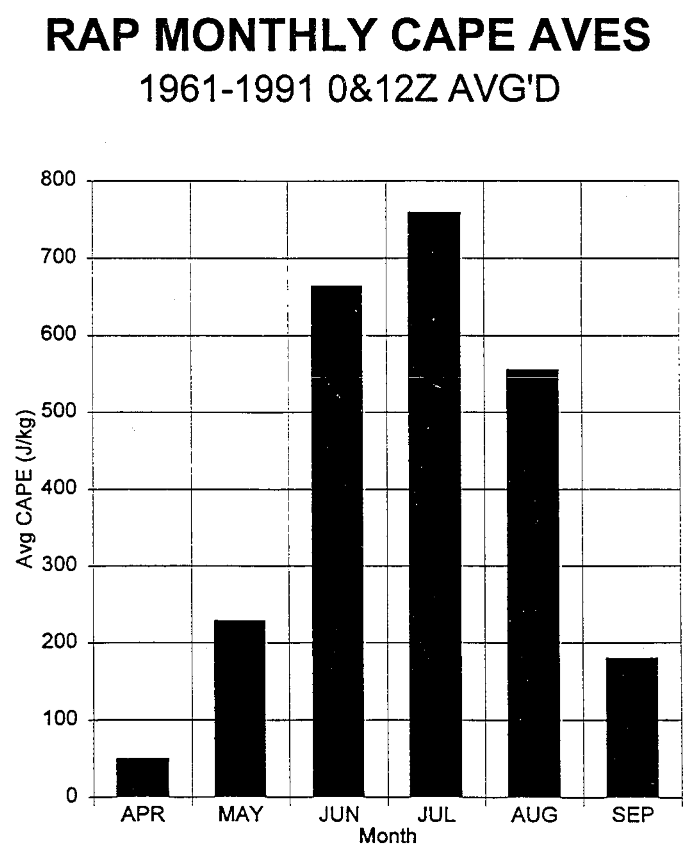


Fig 3.d

APRIL GGW

Column 1	
Mean	32.575
Median	20.7
Mode	0.1
Standard Deviation	33.766
Variance	1140.1
Kurtosis	0.1126
Skewness	1.011
Range	119.13
Minimum	0.1
Maximum	119.23
Sum	2019.6
Count	62
Confidence Level(0.950000)	8.4048

MAY GGW

Column 1	
Mean	105.44
Median	79.89
Mode	24.67
Standard Deviation	84.2559
Variance	7099.06
Kurtosis	-0.1624
Skewness	0.77585
Range	314.18
Minimum	5.61
Maximum	319.79
Sum	6537.25
Count	62
Confidence Level(0.950000)	20.9726

JUN GGW

Column 1	
Mean	291.27
Median	229.3
Mode	NA
Standard Deviation	223.66
Variance	50022
Kurtosis	-0.5774
Skewness	0.7491
Range	797.59
Minimum	14.34
Maximum	811.93
Sum	18059
Count	62
Confidence Level(0.950000)	55.672

JUL GGW

Column 1	
Mean	415.288
Median	302.825
Mode	NA
Standard Deviation	304.104
Variance	92479.1
Kurtosis	0.12144
Skewness	0.97362
Range	1230.62
Minimum	14.61
Maximum	1245.23
Sum	25747.8
Count	62
Confidence Level(0.950000)	75.6962

Table 3

AUG GGW

Column 1	
Mean	257.53
Median	233.88
Mode	NA
Standard Deviation	169.26
Variance	28649
Kurtosis	1.0321
Skewness	1.0088
Range	790.29
Minimum	14.26
Maximum	804.55
Sum	15967
Count	62
Confidence Level(0.950000)	42.132

SEP GGW

Column 1	
Mean	69.961
Median	49.65
Mode	NA
Standard Deviation	61.3554
Variance	3764.49
Kurtosis	1.21143
Skewness	1.30351
Range	255.35
Minimum	2.03
Maximum	257.38
Sum	4337.58
Count	62
Confidence Level(0.950000)	15.2723

APR GTF

Column 1	
Mean	54.723
Median	31.81
Mode	0.93
Standard Deviation	62.459
Variance	3901.1
Kurtosis	3.6709
Skewness	1.5116
Range	317.96
Minimum	0.17
Maximum	318.13
Sum	3392.8
Count	62
Confidence Level(0.950000)	15.547

MAY GTF

Column 1	
Mean	136.245
Median	123.065
Mode	NA
Standard Deviation	130.016
Variance	16904.1
Kurtosis	-1.0334
Skewness	0.53064
Range	436.71
Minimum	0.77
Maximum	437.48
Sum	8447.2
Count	62
Confidence Level(0.950000)	32.363

Table 3

JUN GTF

Column 1	
Mean	282.4
Median	224.82
Mode	NA
Standard Deviation	258.93
Variance	67043
Kurtosis	-0.472
Skewness	0.7569
Range	888.33
Minimum	1.81
Maximum	890.14
Sum	17509
Count	62
Confidence Level(0.950000)	64.451

JUL GTF

Column 1	
Mean	320.486
Median	232.96
Mode	NA
Standard Deviation	275.212
Variance	75741.6
Kurtosis	-0.8301
Skewness	0.70662
Range	968.2
Minimum	5.9
Maximum	974.1
Sum	19870.2
Count	62
Confidence Level(0.950000)	68.5046

AUG GTF

Column 1	
Mean	254.4
Median	200.51
Mode	604.65
Standard Deviation	222.4
Variance	49461
Kurtosis	2.6464
Skewness	1.4864
Range	1109.4
Minimum	1.65
Maximum	1111
Sum	15773
Count	62
Confidence Level(0.950000)	55.359

SEP GTF

Column 1	
Mean	90.865
Median	70.84
Mode	4.33
Standard Deviation	90.4946
Variance	8189.27
Kurtosis	1.29056
Skewness	1.16644
Range	405.97
Minimum	0.5
Maximum	406.47
Sum	5633.63
Count	62
Confidence Level(0.950000)	22.5255

Table 3

APR LND

Column 1	
Mean	75.622
Median	46.845
Mode	0
Standard Deviation	85.211
Variance	7261
Kurtosis	0.4382
Skewness	1.1233
Range	305.27
Minimum	0
Maximum	305.27
Sum	4688.6
Count	62
Confidence Level(0.950000)	21.21

MAY LND

Column 1	
Mean	170.995
Median	115.4
Mode	NA
Standard Deviation	180.536
Variance	32593.4
Kurtosis	1.30278
Skewness	1.2133
Range	742.59
Minimum	0.93
Maximum	743.52
Sum	10601.7
Count	62
Confidence Level(0.950000)	44.9383

JUN LND

Column 1	
Mean	351.85
Median	277.78
Mode	NA
Standard Deviation	314.86
Variance	99135
Kurtosis	-0.8368
Skewness	0.5825
Range	1196.6
Minimum	3.97
Maximum	1200.5
Sum	21814
Count	62
Confidence Level(0.950000)	78.373

JUL LND

Column 1	
Mean	385.709
Median	202.73
Mode	NA
Standard Deviation	344.986
Variance	119015
Kurtosis	-0.5744
Skewness	0.68131
Range	1294.87
Minimum	18.81
Maximum	1313.68
Sum	23914
Count	62
Confidence Level(0.950000)	85.8724

Table 3

AUG LND

Column 1	
Mean	328.12
Median	247.47
Mode	NA
Standard Deviation	316.88
Variance	100413
Kurtosis	-0.0347
Skewness	0.8764
Range	1169.9
Minimum	7.61
Maximum	1177.5
Sum	20343
Count	62
Confidence Level(0.950000)	78.877

SEP LND

Column 1	
Mean	135.595
Median	83.68
Mode	NA
Standard Deviation	144.398
Variance	20850.8
Kurtosis	3.88072
Skewness	1.56308
Range	748.94
Minimum	1.13
Maximum	750.07
Sum	8406.9
Count	62
Confidence Level(0.950000)	35.9429

APR RAP

Column 1	
Mean	50.325
Median	39.6
Mode	0
Standard Deviation	44.99
Variance	2024.1
Kurtosis	-0.3513
Skewness	0.7709
Range	161.33
Minimum	0
Maximum	161.33
Sum	3120.2
Count	62
Confidence Level(0.950000)	11.199

MAY RAP

Column 1	
Mean	229.474
Median	177.36
Mode	NA
Standard Deviation	211.746
Variance	44836.4
Kurtosis	3.77783
Skewness	1.59367
Range	1093.29
Minimum	1.61
Maximum	1094.9
Sum	14227.4
Count	62
Confidence Level(0.950000)	52.7069

Table 3

JUN RAP

Column 1	
Mean	664.38
Median	529.44
Mode	NA
Standard Deviation	478.07
Variance	228550
Kurtosis	-0.173
Skewness	0.7766
Range	1934.5
Minimum	41.4
Maximum	1975.9
Sum	41191
Count	62
Confidence Level(0.950000)	119

JUL RAP

Column 1	
Mean	760.021
Median	676.405
Mode	NA
Standard Deviation	433.942
Variance	188306
Kurtosis	0.44535
Skewness	0.96153
Range	1935.67
Minimum	165.65
Maximum	2101.32
Sum	47121.3
Count	62
Confidence Level(0.950000)	108.015

AUG RAP

Column 1	
Mean	555.9
Median	487.89
Mode	613.42
Standard Deviation	335.25
Variance	112390
Kurtosis	2.3858
Skewness	1.3758
Range	1647
Minimum	74.77
Maximum	1721.8
Sum	34466
Count	62
Confidence Level(0.950000)	83.448

SEP RAP

Column 1	
Mean	180.359
Median	148.965
Mode	NA
Standard Deviation	121.239
Variance	14699
Kurtosis	1.63244
Skewness	1.17508
Range	580.89
Minimum	19.61
Maximum	600.5
Sum	11182.3
Count	62
Confidence Level(0.950000)	30.1784

Table 3

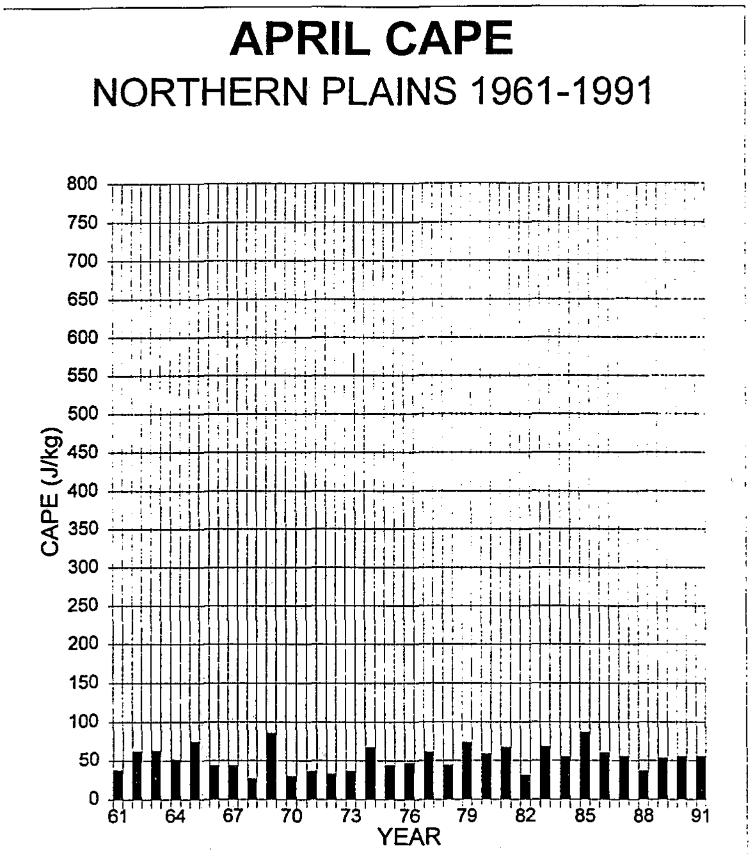


Fig 4.a

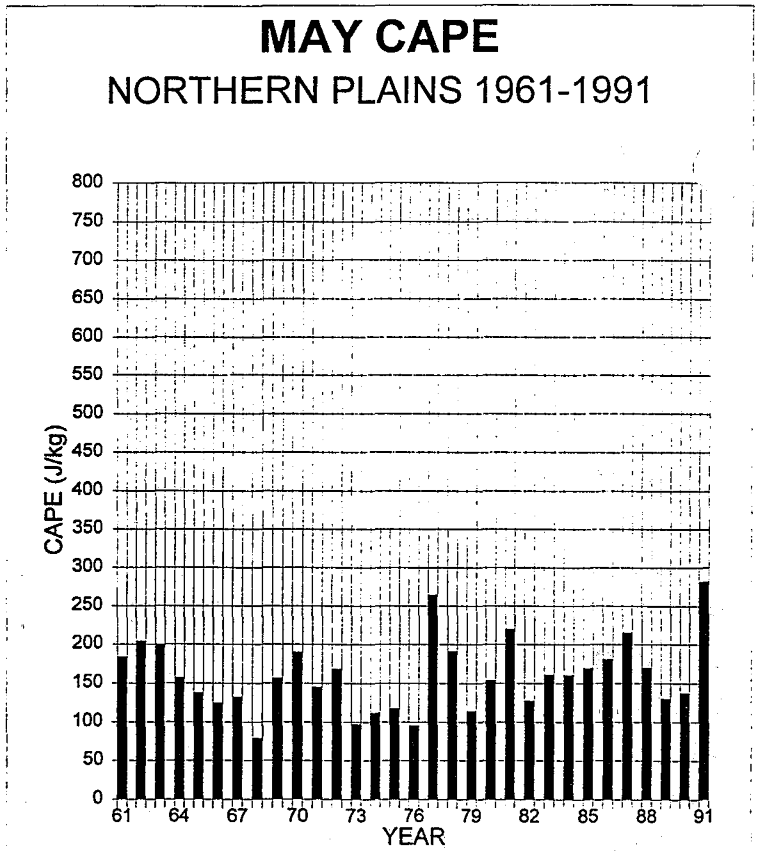


Fig 4.b

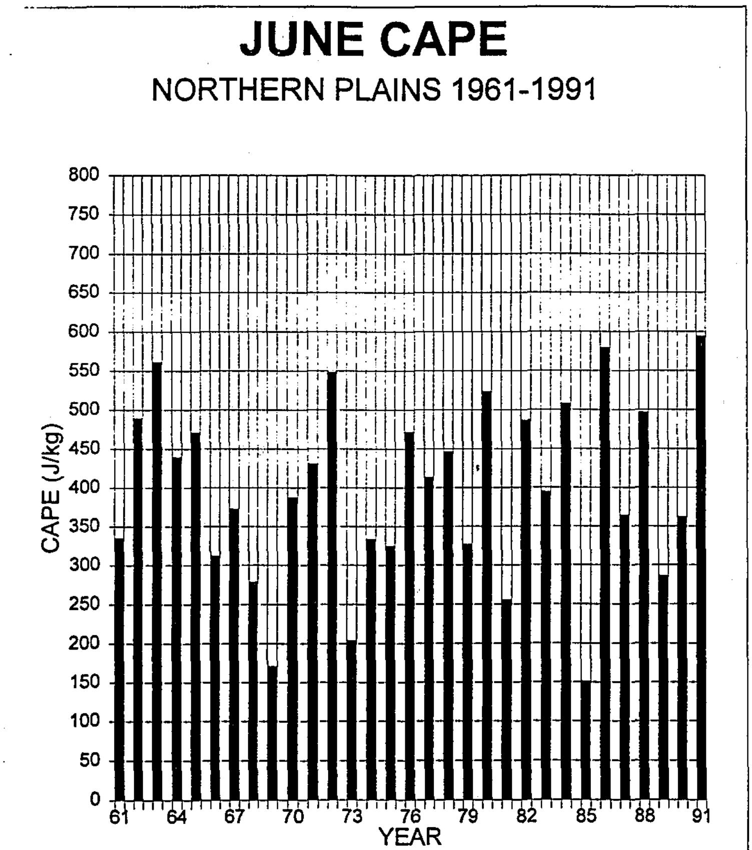


Fig 4.c

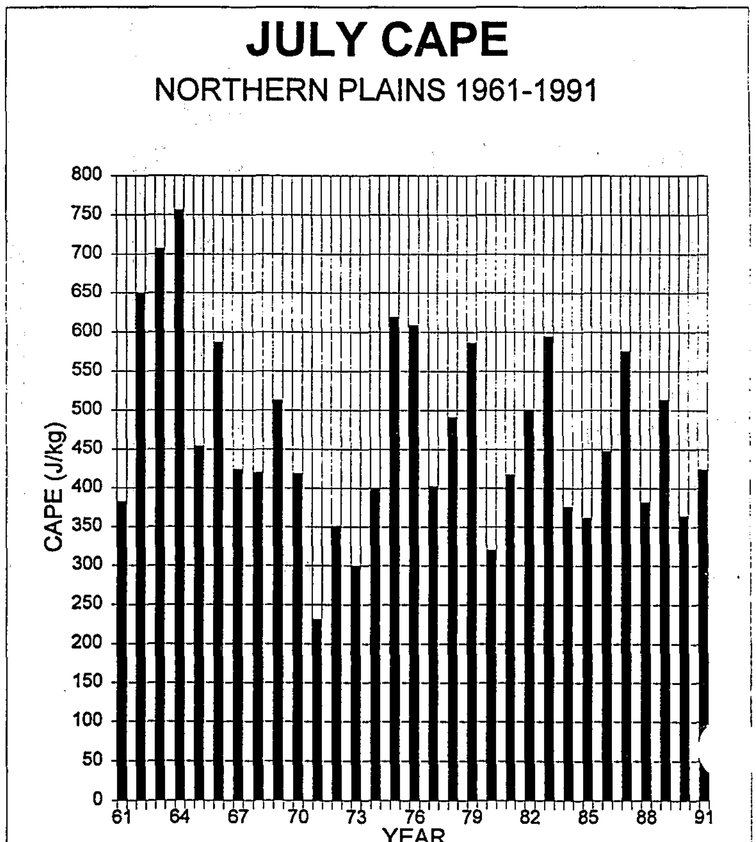
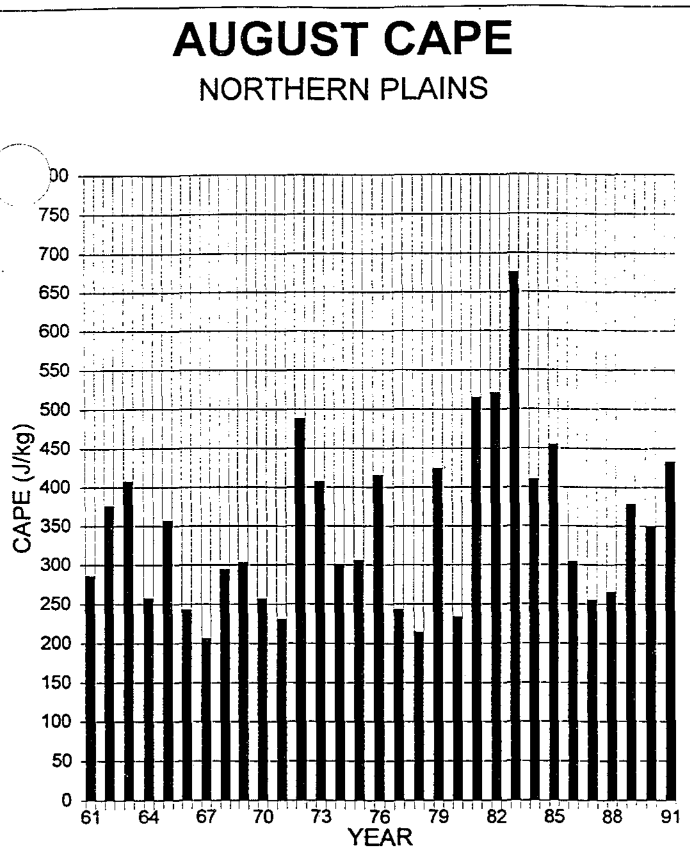
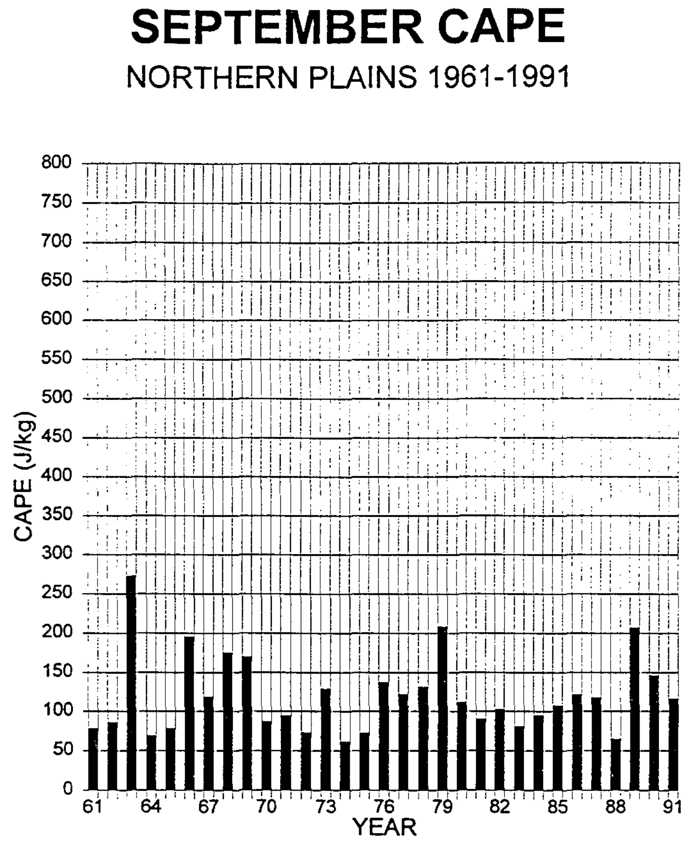


Fig 4.d


AUGUST CAPE
NORTHERN PLAINS
CAPE (J/kg)
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
61
64
67
70
73
76
79
82
85
88
91
YEAR
Fig 4.e


SEPTEMBER CAPE
NORTHERN PLAINS 1961-1991
CAPE (J/kg)
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
61
64
67
70
73
76
79
82
85
88
91
YEAR
Fig 4.f

APRIL CAPE

Column 1	
Mean	53.31121
Median	29.785
Mode	NA
Standard Deviation	61.4304
Variance	3773.694
Kurtosis	3.43114
Skewness	1.668628
Range	318.13
Minimum	0
Maximum	318.13
Sum	13221.18
Count	248
Confidence Level(0.95000	7.645495

MAY CAPE

Column 1	
Mean	158.8254
Median	110.09
Mode	NA
Standard Deviation	167.3261
Variance	27998.01
Kurtosis	5.008335
Skewness	1.776482
Range	1094.1
Minimum	0.77
Maximum	1094.9
Sum	39388.71
Count	248
Confidence Level(0.950000	20.82504

JUNE CAPE

Column 1	
Mean	397.475
Median	325.07
Mode	NA
Standard Deviation	366.6001
Variance	134395.7
Kurtosis	2.102554
Skewness	1.352078
Range	1974.04
Minimum	1.81
Maximum	1975.85
Sum	98573.8
Count	248
Confidence Level(0.95000	45.62626

JULY CAPE

Column 1	
Mean	470.3759
Median	398.63
Mode	NA
Standard Deviation	383.0151
Variance	146700.5
Kurtosis	1.312841
Skewness	1.100266
Range	2095.4
Minimum	5.9
Maximum	2101.32
Sum	116653.2
Count	248
Confidence Level(0.950000	47.66923

Table 4
(1)

JGUST CAPE

Column 1	
Mean	348.9863
Median	282.52
Mode	NA
Standard Deviation	295.0357
Variance	87046.08
Kurtosis	2.789377
Skewness	1.420171
Range	1720.15
Minimum	1.65
Maximum	1721.8
Sum	86548.59
Count	248
Confidence Level(0.95000	36.71951

SEPTEMBER CAPE

Column 1	
Mean	119.1951
Median	83
Mode	4.33
Standard Deviation	116.3964
Variance	13548.13
Kurtosis	4.070825
Skewness	1.622871
Range	750.02
Minimum	0.5
Maximum	750.07
Sum	29560.39
Count	248
Confidence Level(0.950000	14.48645

Table 4

(2)

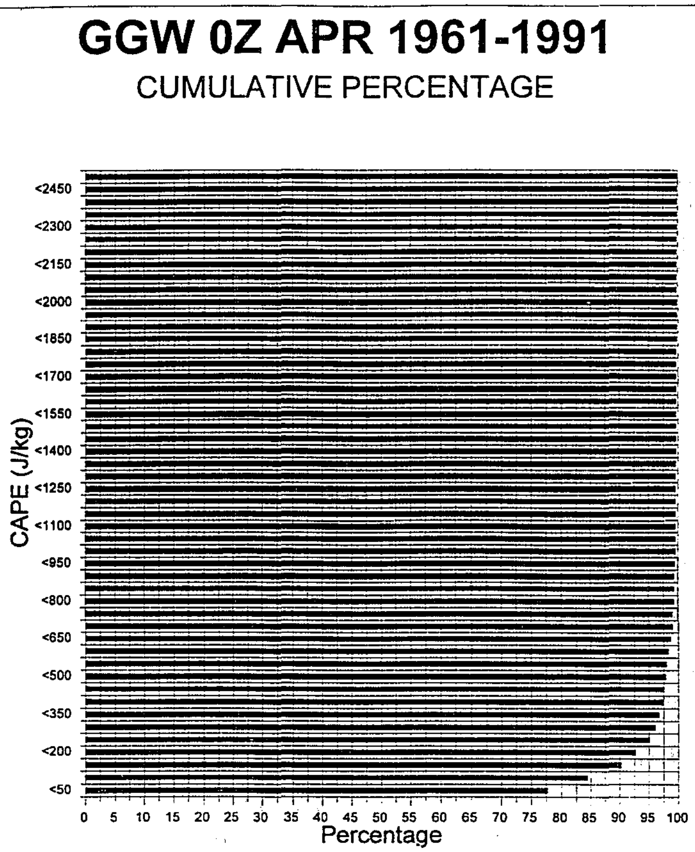


Fig 5.a

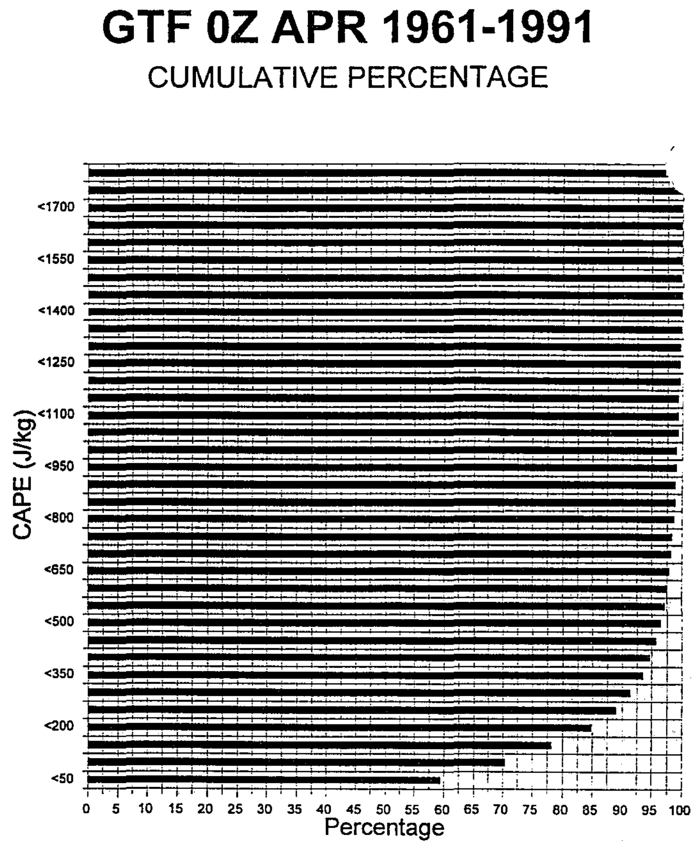


Fig 5.b

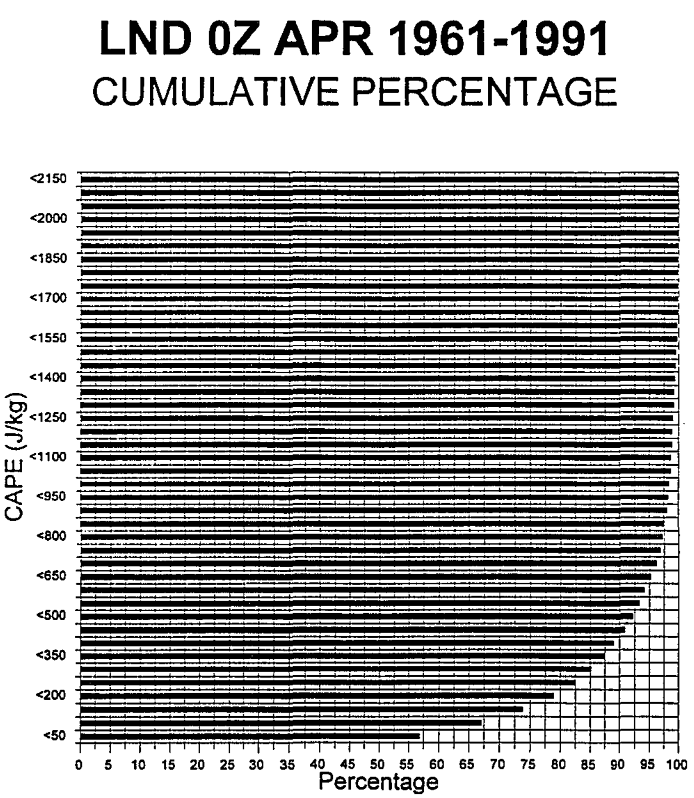


Fig 5.c

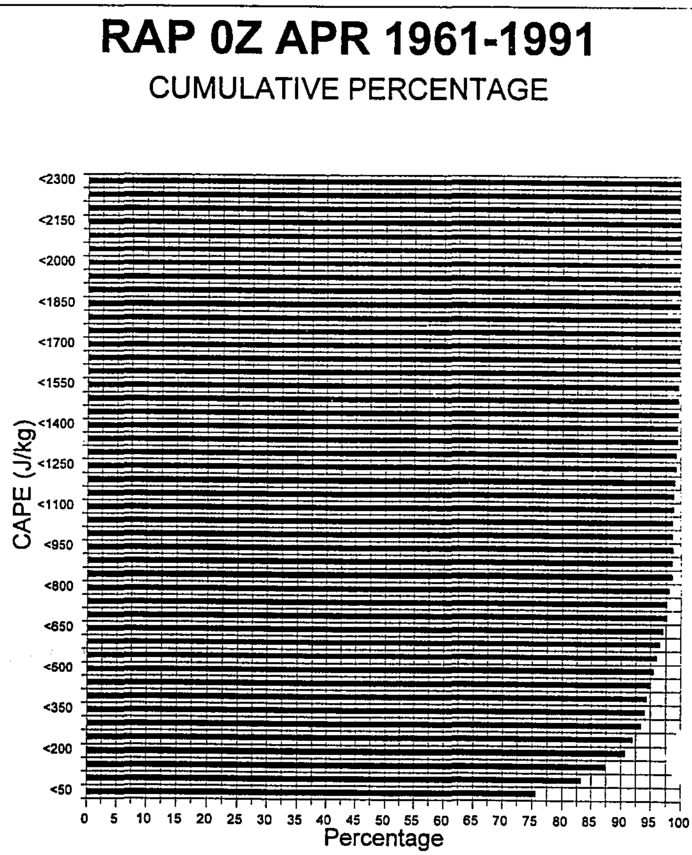


Fig 5.d

GGW APR 0Z

Column 1	
Mean	59.19828
Median	1
Mode	0
Standard Deviation	174.3984
Variance	30414.8
Kurtosis	90.60563
Skewness	8.067441
Range	2487
Minimum	0
Maximum	2487
Sum	54936
Count	928
Confidence Level(0.950000)	11.22061

GTF APR 0Z

Column 1	
Mean	103.89479
Median	29
Mode	0
Standard Deviation	184.2373
Variance	33943.382
Kurtosis	20.603973
Skewness	3.835401
Range	1731
Minimum	0
Maximum	1731
Sum	95791
Count	922
Confidence Level(0.950000)	11.892145

LND APR 0Z

Column 1	
Mean	143.1717
Median	36
Mode	0
Standard Deviation	249.0997
Variance	62050.69
Kurtosis	12.92189
Skewness	3.130038
Range	2078
Minimum	0
Maximum	2078
Sum	132577
Count	926
Confidence Level(0.950000)	16.04412

RAP ARP 0Z

Column 1	
Mean	80.734136
Median	0
Mode	0
Standard Deviation	216.06792
Variance	46685.345
Kurtosis	32.442909
Skewness	5.0421876
Range	2227
Minimum	0
Maximum	2227
Sum	73791
Count	914
Confidence Level(0.950000)	14.00765

Table 5

GGW 0Z MAY 1961-1991
CUMULATIVE PERCENTAGE

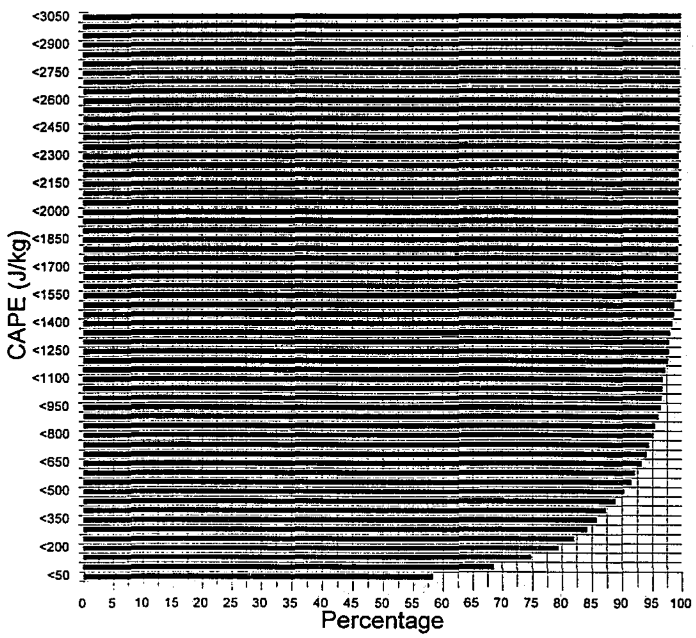


Fig 6.a

GTF 0Z MAY 1961-1991
CUMULATIVE PERCENTAGE

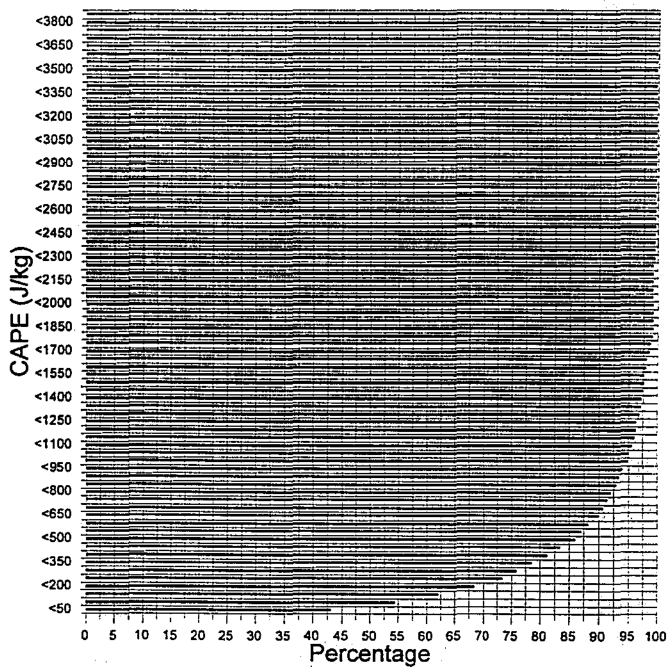


Fig 6.b

LND 0Z MAY 1961-1991
CUMULATIVE PERCENTAGE

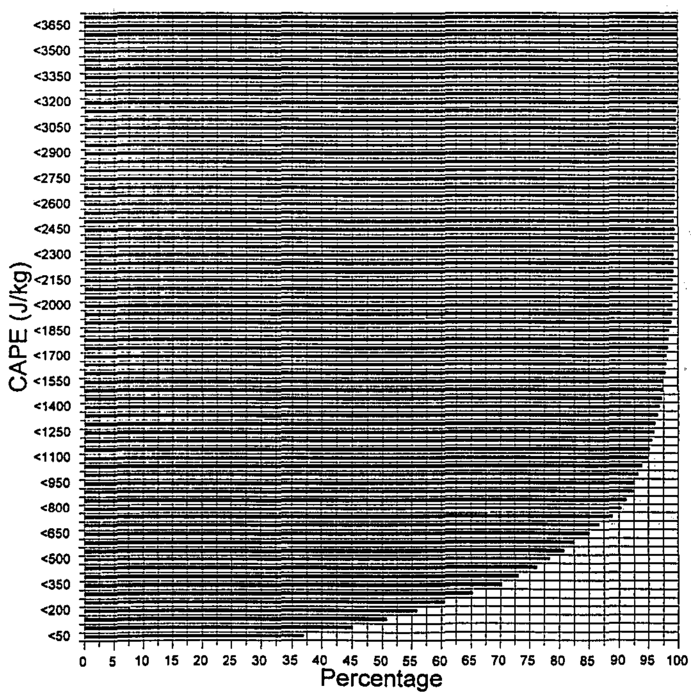


Fig 6.c

RAP 0Z MAY 1961-1991
CUMULATIVE PERCENTAGE

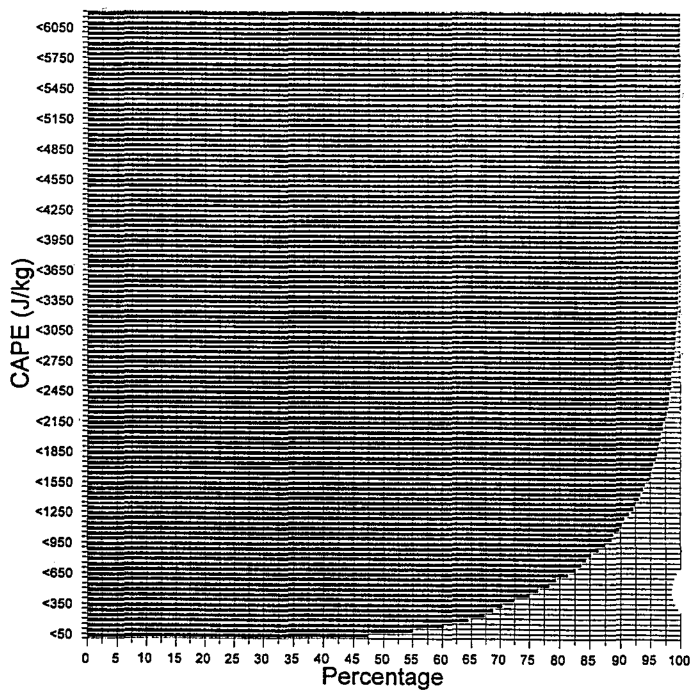


Fig 6.d

GGW 0Z MAY

Column 1	
Mean	162.119
Median	26
Mode	0
Standard Deviation	329.801
Variance	108769
Kurtosis	18.7058
Skewness	3.75911
Range	2930
Minimum	0
Maximum	2930
Sum	155148
Count	957
Confidence Level(0.950000)	20.8951

GTF 0Z MAY

Column 1	
Mean	248.168
Median	89
Mode	0
Standard Deviation	412.386
Variance	170062
Kurtosis	16.0288
Skewness	3.39511
Range	3670
Minimum	0
Maximum	3670
Sum	233030
Count	939
Confidence Level(0.950000)	26.3766

LND 0Z MAY

Column 1	
Mean	316.546
Median	160.5
Mode	0
Standard Deviation	446.92
Variance	199737
Kurtosis	12.2664
Skewness	2.88946
Range	3607
Minimum	0
Maximum	3607
Sum	300719
Count	950
Confidence Level(0.950000)	28.4195

RAP 0Z MAY

Column 1	
Mean	373.128
Median	77
Mode	0
Standard Deviation	640.175
Variance	409824
Kurtosis	13.6307
Skewness	3.05144
Range	6132
Minimum	0
Maximum	6132
Sum	351860
Count	943
Confidence Level(0.950000)	40.8593

Table 6

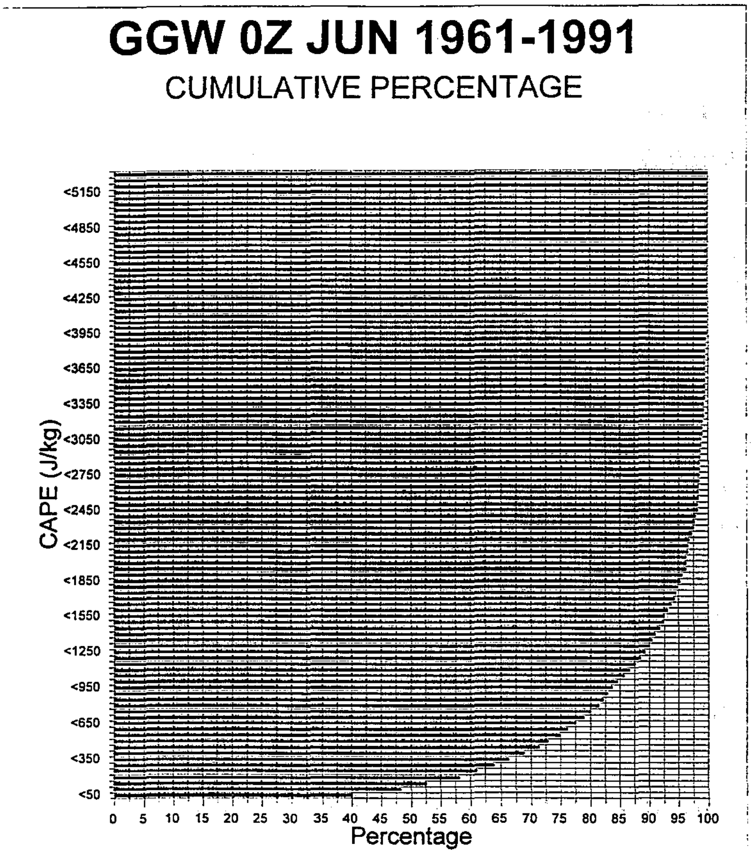


Fig 7.a

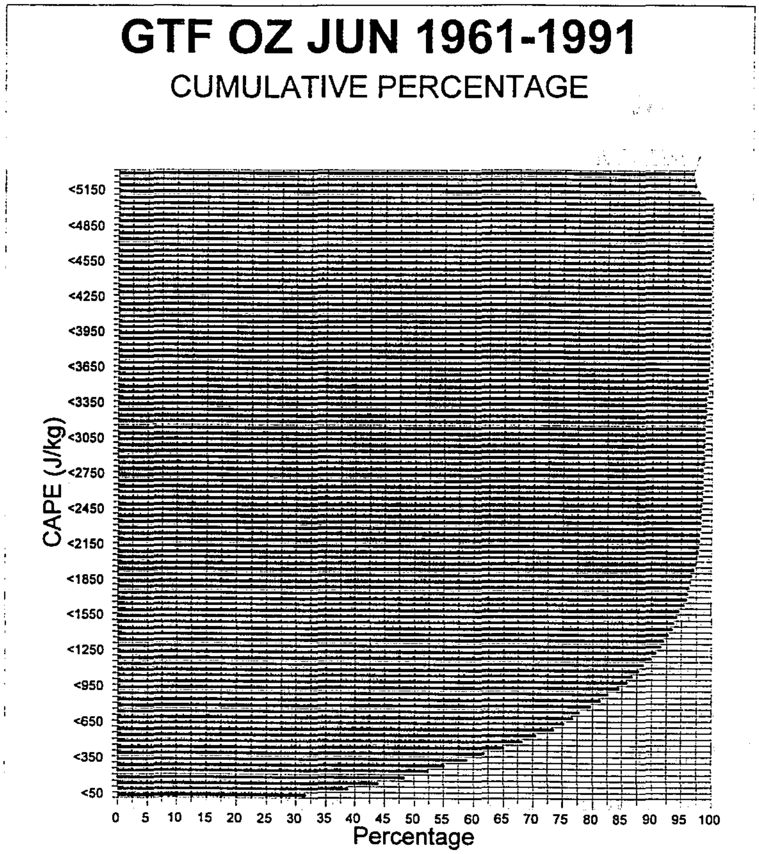


Fig 7.b

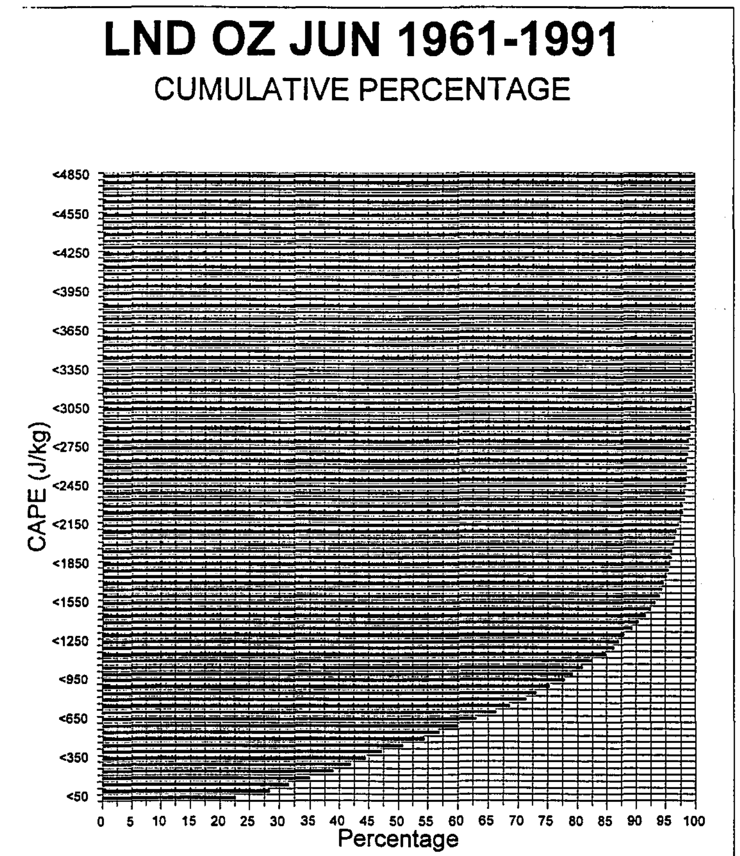


Fig 7.c

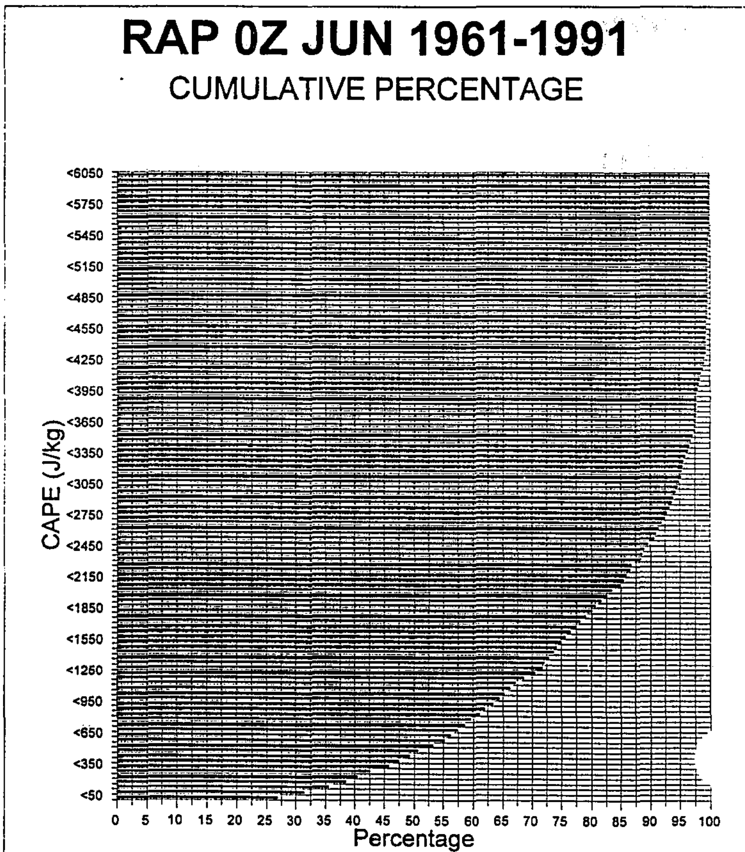


Fig 7.d

GGW JUN 0Z

Column 1	
Mean	449.8368
Median	154
Mode	0
Standard Deviation	679.71115
Variance	462007.25
Kurtosis	8.0790639
Skewness	2.508381
Range	5251
Minimum	0
Maximum	5251
Sum	410701
Count	913
Confidence Level(0.950000)	44.089696

GTF JUN 0Z

Column 1	
Mean	500.1511
Median	291
Mode	0
Standard Deviation	649.9935
Variance	422491.6
Kurtosis	11.8099
Skewness	2.797894
Range	5187
Minimum	0
Maximum	5187
Sum	443634
Count	887
Confidence Level(0.950000)	42.77552

LND JUN 0Z

Column 1	
Mean	624.99454
Median	478
Mode	0
Standard Deviation	633.41316
Variance	401212.23
Kurtosis	5.5134046
Skewness	1.8487048
Range	4818
Minimum	0
Maximum	4818
Sum	571870
Count	915
Confidence Level(0.950000)	41.041633

RAP JUN 0Z

Column 1	
Mean	999.0978
Median	563.5
Mode	0
Standard Deviation	1102.114
Variance	1214656
Kurtosis	1.639532
Skewness	1.388866
Range	5975
Minimum	0
Maximum	5975
Sum	899188
Count	900
Confidence Level(0.950000)	72.00348

Table 7

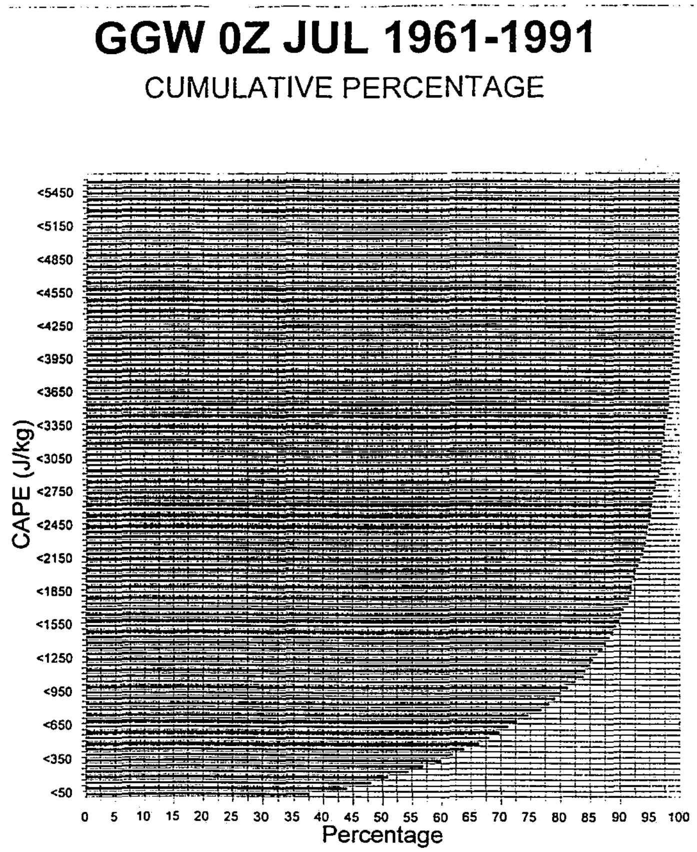


Fig 8.a

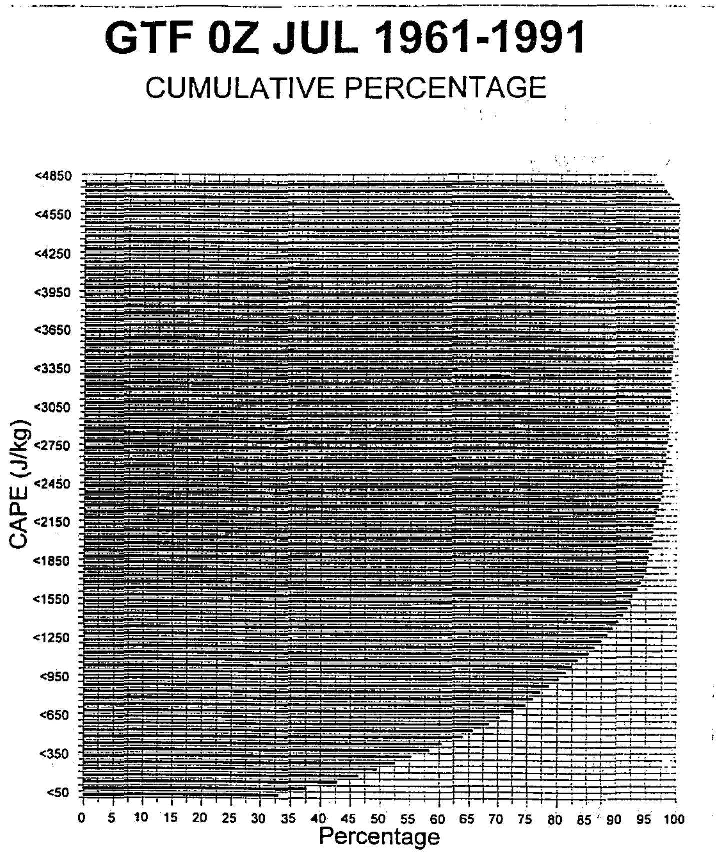


Fig 8.b

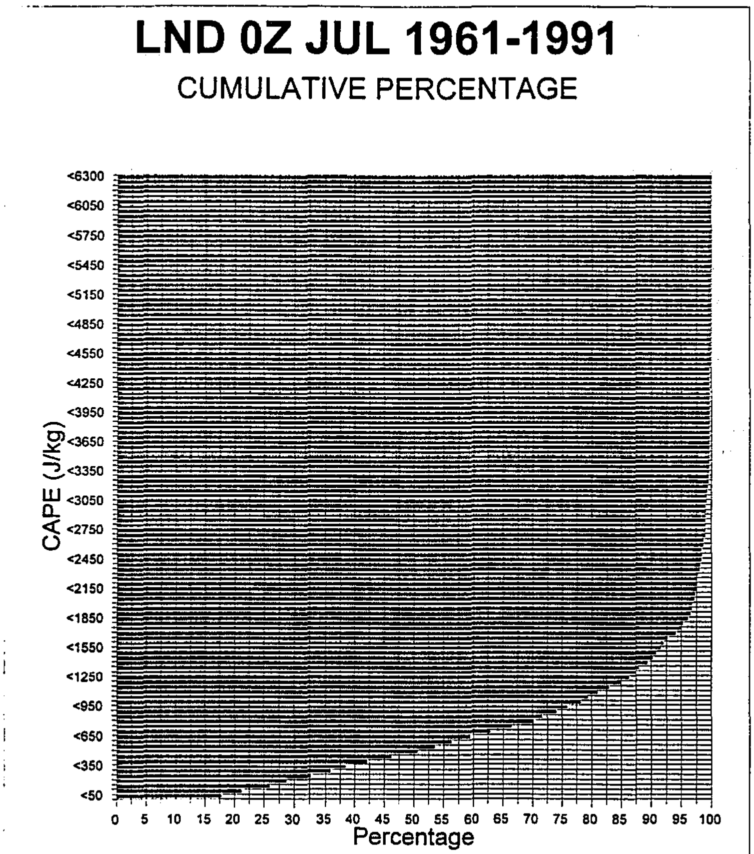


Fig 8.c

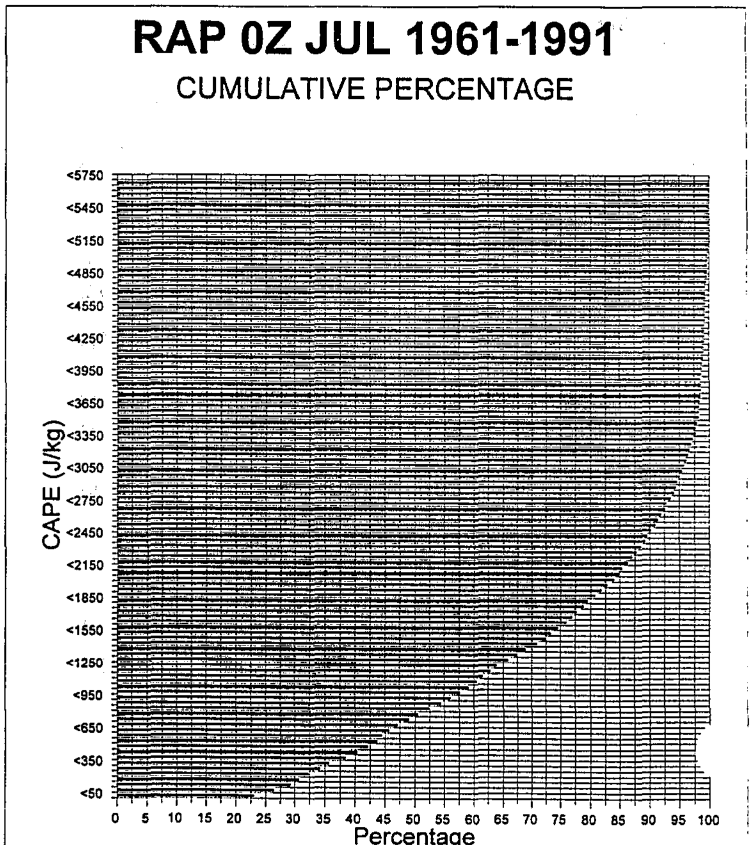


Fig 8.d

GGW JUL 0Z

Column 1	
Mean	588.5825
Median	217
Mode	0
Standard Deviation	880.4417
Variance	775177.5
Kurtosis	6.288153
Skewness	2.378578
Range	5454
Minimum	0
Maximum	5454
Sum	552679
Count	939
Confidence Level(0.950000)	56.31394

GTF JUL 0Z

Column 1	
Mean	559.8277
Median	316
Mode	0
Standard Deviation	706.38336
Variance	498977.45
Kurtosis	6.3184167
Skewness	2.1980004
Range	4736
Minimum	0
Maximum	4736
Sum	513362
Count	917
Confidence Level(0.950000)	45.719754

LND JUL 0Z

Column 1	
Mean	689.9825
Median	549.5
Mode	0
Standard Deviation	652.7268
Variance	426052.3
Kurtosis	10.7433
Skewness	2.29096
Range	6289
Minimum	0
Maximum	6289
Sum	632024
Count	916
Confidence Level(0.950000)	42.26996

RAP JUL 0Z

Column 1	
Mean	1088.2557
Median	872
Mode	0
Standard Deviation	1025.3832
Variance	1051410.7
Kurtosis	1.1621426
Skewness	1.1322586
Range	5613
Minimum	0
Maximum	5613
Sum	1000107
Count	919
Confidence Level(0.950000)	66.294352

Table 8

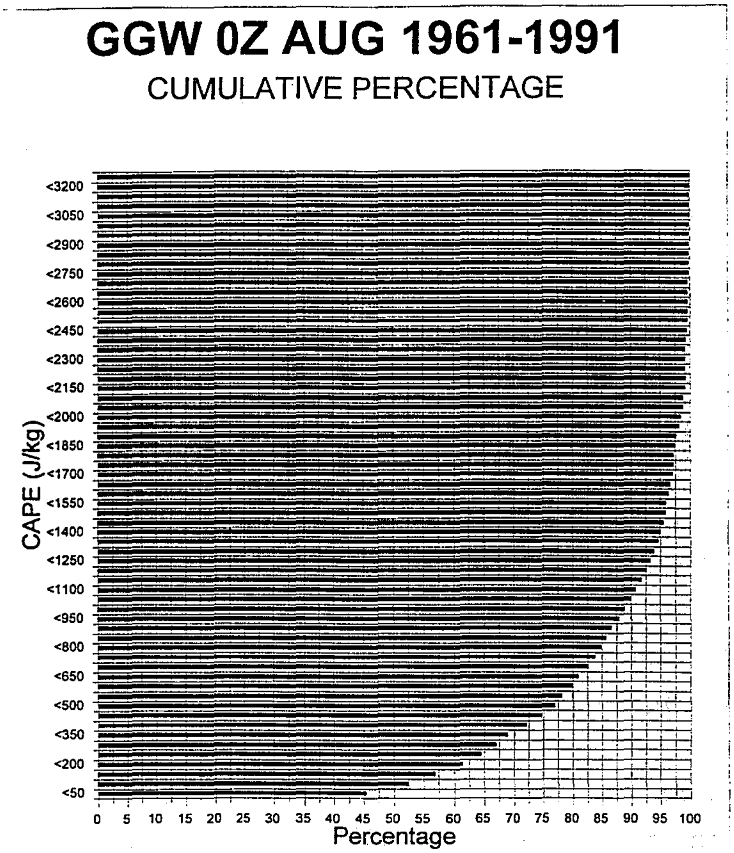


Fig 9.a

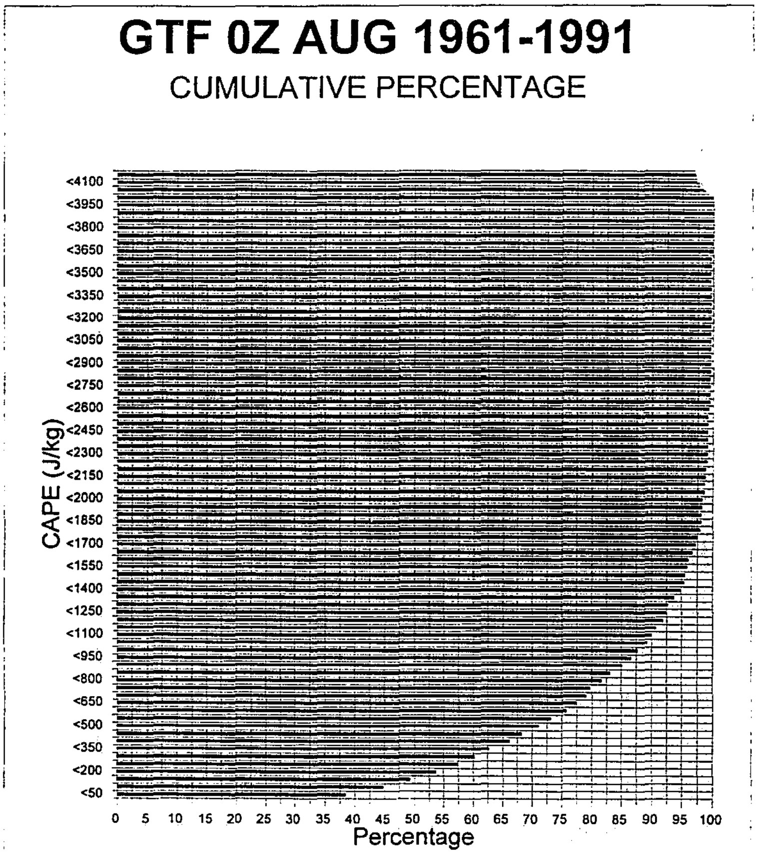


Fig 9.b

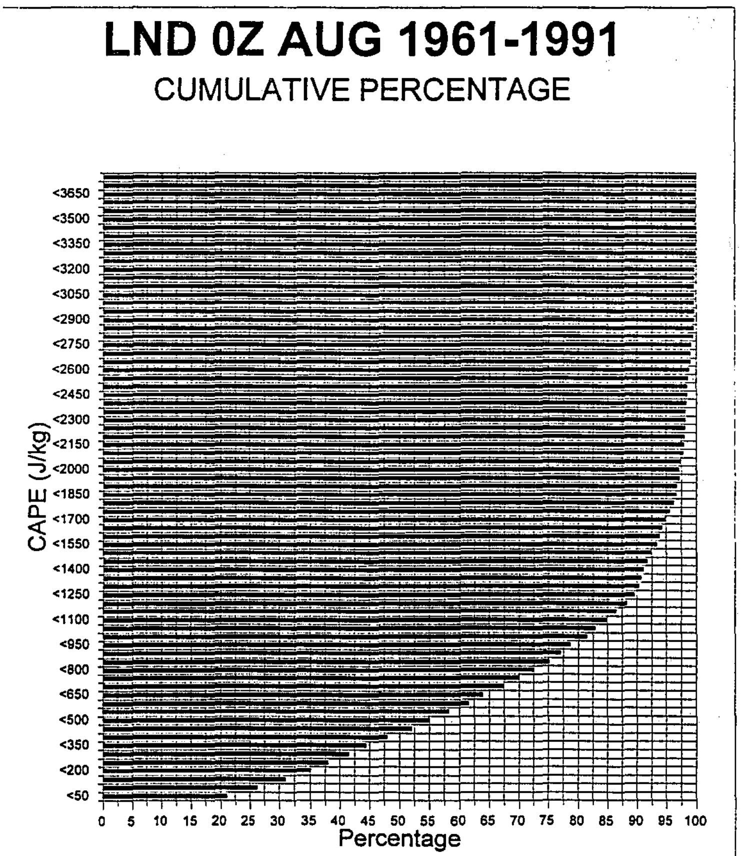


Fig 9.c

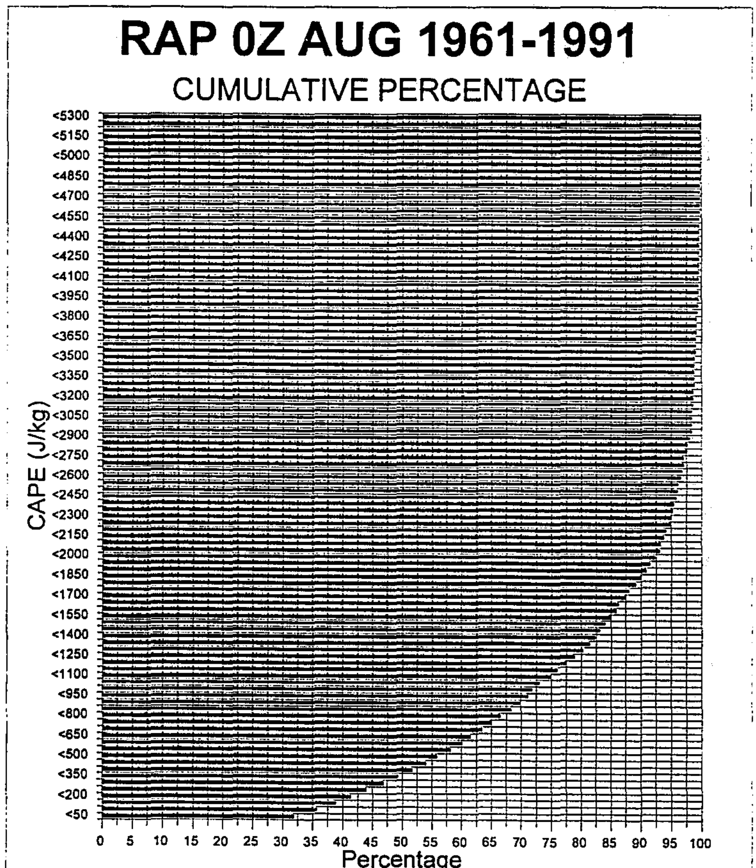


Fig 9.d

GGW 0Z AUG

Column 1	
Mean	337.9916
Median	91
Mode	0
Standard Deviation	507.0769
Variance	257127
Kurtosis	4.845293
Skewness	2.104239
Range	3185
Minimum	0
Maximum	3185
Sum	322782
Count	955
Confidence Level(0.95000	32.16031

GTF 0Z AUG

Column 1	
Mean	409.391
Median	193
Mode	0
Standard Deviation	541.572
Variance	293300
Kurtosis	7.31743
Skewness	2.23671
Range	4055
Minimum	0
Maximum	4055
Sum	380734
Count	930
Confidence Level(0.9500	34.8067

LND 0Z AUG

Column 1	
Mean	602.5087
Median	475
Mode	0
Standard Deviation	580.5021
Variance	336982.7
Kurtosis	3.289554
Skewness	1.561529
Range	3674
Minimum	0
Maximum	3674
Sum	554308
Count	920
Confidence Level(0.95000	37.51094

RAP 0Z AUG

Column 1	
Mean	709.947
Median	410.5
Mode	0
Standard Deviation	833.732
Variance	695109
Kurtosis	3.21906
Skewness	1.63653
Range	5243
Minimum	0
Maximum	5243
Sum	668770
Count	942
Confidence Level(0.9500	53.2413

Table 9

GGW 0Z SEP 1961-1991
CUMULATIVE PERCENTAGE

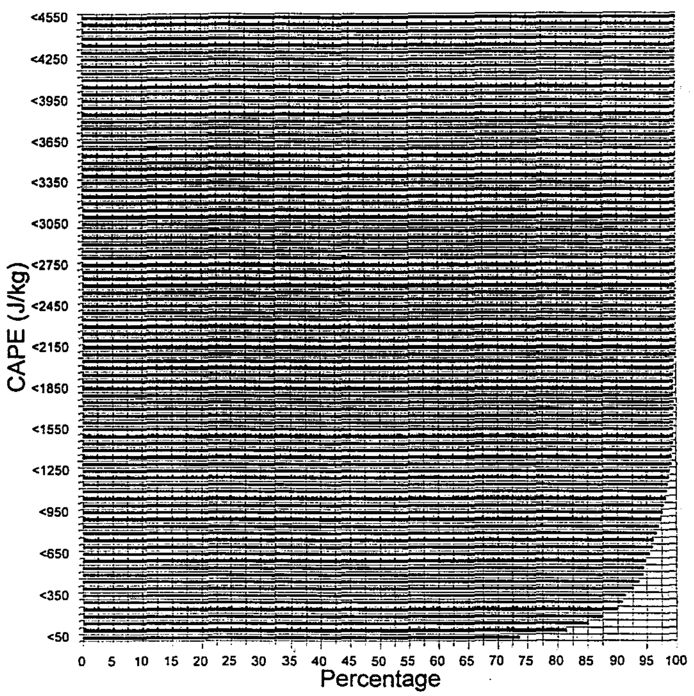


Fig 10.a

GTF 0Z SEP 1961-1991
CUMULATIVE PERCENTAGE

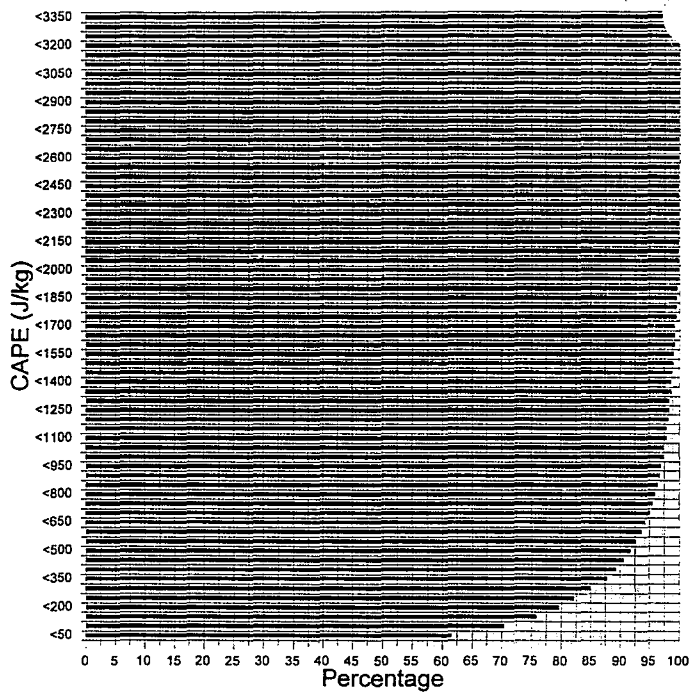


Fig 10.b

LND 0Z SEP 1961-1991
CUMULATIVE PERCENTAGE

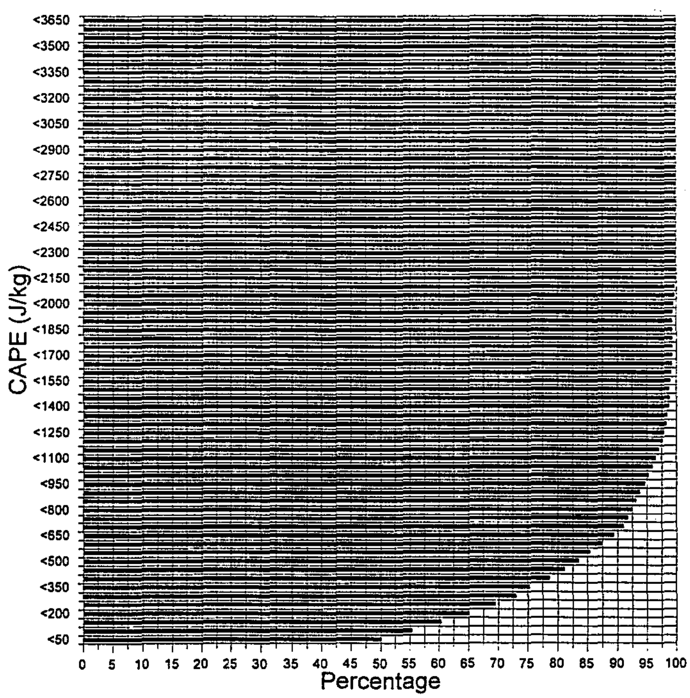


Fig 10.c

RAP 0Z SEP 1961-1991
CUMULATIVE PERCENTAGE

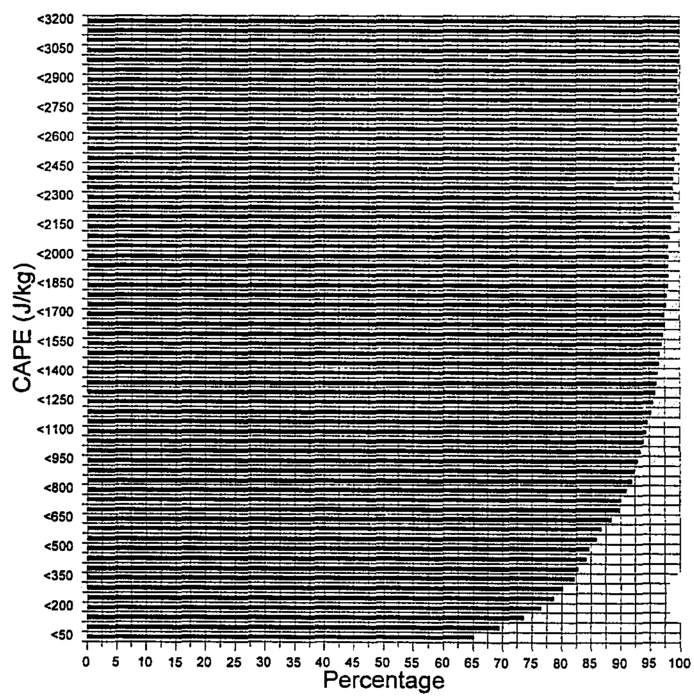


Fig 10.d

GGW SEP 0Z

Column 1	
Mean	103.59697
Median	0
Mode	0
Standard Deviation	293.64996
Variance	86230.297
Kurtosis	71.723245
Skewness	6.668681
Range	4521
Minimum	0
Maximum	4521
Sum	95620
Count	923
Confidence Level(0.950000)	18.94424

GTF SEP 0Z

Column 1	
Mean	149.835
Median	12
Mode	0
Standard Deviation	312.4584
Variance	97630.25
Kurtosis	23.8677
Skewness	4.116955
Range	3229
Minimum	0
Maximum	3229
Sum	137099
Count	915
Confidence Level(0.950000)	20.24556

LND SEP 0Z

Column 1	
Mean	241.99674
Median	70
Mode	0
Standard Deviation	364.94289
Variance	133183.31
Kurtosis	12.167169
Skewness	2.7403903
Range	3564
Minimum	0
Maximum	3564
Sum	222395
Count	919
Confidence Level(0.950000)	23.594742

RAP SEP 0Z

Column 1	
Mean	223.762
Median	2
Mode	0
Standard Deviation	467.2807
Variance	218351.3
Kurtosis	11.22228
Skewness	3.136008
Range	3123
Minimum	0
Maximum	3123
Sum	205861
Count	920
Confidence Level(0.950000)	30.19479

Table 10

Appendix A
Definitions

Central Tendency- Central or average values which describe the usual behavior of an element which varies in a distribution.

Mean - Addition of all values in a sample divided by the total number of cases used in that sample.

Median - The middle or central value of a numeric array.

Mode - The number in an array which occurs with the greatest frequency.

Variance - The average squared distance between a set of data points and their mean.

Standard Deviation - The square root of variance.

Kurtosis - A measure of a distribution's normality or the degree of peakness or flatness. Few sample points near the median indicate low kurtosis. Most of the observations near the center yield high kurtosis numbers.

Skewness - A measure of the degree of asymmetry around a distribution's mean value. A positive value yields a distribution which is skewed to the right (the median is less than the mean).

Confidence Interval for the Mean - A way to test, with a pre-specified amount of certainty, that a population's true mean will be within a certain interval around the sample mean. The parameters used to calculate the interval number are the chosen alpha value (1.00-the confidence level), the standard deviation, and the size of the sample.

Example
A mean was calculated from 1000 data points and this mean was exactly 490. If the population standard deviation is 0.50 and a confidence level of 95% is chosen, then the confidence interval number is 0.03099

This means that the true mean of the population will lie between plus or minus 0.03099 from the mean with 95% confidence.

144 Arizona Cool Season Climatological Surface Wind and Pressure Gradient Study. Ira S. Brenner, May 1979. (PB298900/AS)
146 The BART Experiment. Morris S. Webb, October 1979. (PB80 155112)
147 Occurrence and Distribution of Flash Floods in the Western Region. Thomas L. Dietrich, December 1979. (PB80 160344)
149 Misinterpretations of Precipitation Probability Forecasts. Allan H. Murphy, Sarah Lichtenstein, Baruch Fischhoff, and Robert L. Winkler, February 1980. (PB80 174576)
150 Annual Data and Verification Tabulation - Eastern and Central North Pacific Tropical Storms and Hurricanes 1979. Emil B. Gunther and Staff, EPHC, April 1980. (PB80 220486)
NMC Model Performance in the Northeast Pacific. James E. Overland, PMEL-ERL, April 1980. (PB80 196033)
Climate of Salt Lake City, Utah. William J. Alder, Sean T. Buchanan, William Cope (Retired), James A. Cisco, Craig C. Schmidt, Alexander R. Smith (Retired), Wilbur E. Figgins (Retired), April 1996 - Sixth Revision (PB96 175583)
153 An Automatic Lightning Detection System in Northern California. James E. Rea and Chris E. Fontana, June 1980. (PB80 225592)
154 Regression Equation for the Peak Wind Gust 6 to 12 Hours in Advance at Great Falls During Strong Downslope Wind Storms. Michael J. Oard, July 1980. (PB91 108367)
155 A Raininess Index for the Arizona Monsoon. John H. Ten Harkel, July 1980. (PB81 106494)
156 The Effects of Terrain Distribution on Summer Thunderstorm Activity at Reno, Nevada. Christopher Dean Hill, July 1980. (PB81 102501)
157 An Operational Evaluation of the Scofield/Oliver Technique for Estimating Precipitation Rates from Satellite Imagery. Richard Ochoa, August 1980. (PB81 108227)
158 Hydrology Practicum. Thomas Dietrich, September 1980. (PB81 134033)
159 Tropical Cyclone Effects on California. Arnold Court, October 1980. (PB81 133779)
160 Eastern North Pacific Tropical Cyclone Occurrences During Intraseasonal Periods. Preston W. Leftwich and Gail M. Brown, February 1981. (PB81 205494)
161 Solar Radiation as a Sole Source of Energy for Photovoltaics in Las Vegas, Nevada, for July and December. Darryl Randerson, April 1981. (PB81 224503)
162 A Systems Approach to Real-Time Runoff Analysis with a Deterministic Rainfall-Runoff Model. Robert J.C. Burnash and R. Larry Ferral, April 1981. (PB81 224495)
163 A Comparison of Two Methods for Forecasting Thunderstorms at Luke Air Force Base, Arizona. LTC Keith R. Cooley, April 1981. (PB81 225393)
164 An Objective Aid for Forecasting Afternoon Relative Humidity Along the Washington Cascade East Slopes. Robert S. Robinson, April 1981. (PB81 23078)
165 Annual Data and Verification Tabulation, Eastern North Pacific Tropical Storms and Hurricanes 1980. Emil B. Gunther and Staff, May 1981. (PB82 230336)
166 Preliminary Estimates of Wind Power Potential at the Nevada Test Site. Howard G. Booth, June 1981. (PB82 127036)
167 ARAP User's Guide. Mark Mathewson, July 1981, Revised September 1981. (PB82 196783)
168 Forecasting the Onset of Coastal Gales Off Washington-Oregon. John R. Zimmerman and William D. Burton, August 1981. (PB82 127051)
169 A Statistical-Dynamical Model for Prediction of Tropical Cyclone Motion in the Eastern North Pacific Ocean. Preston W. Leftwich, Jr., October 1981. (PB82195298)
170 An Enhanced Plotter for Surface Airways Observations. Andrew J. Spry and Jeffrey L. Anderson, October 1981. (PB82 153883)
171 Verification of 72-Hour 500-MB Map-Type Predictions. R.F. Quiring, November 1981. (PB82-158098)
172 Forecasting Heavy Snow at Wenatchee, Washington. James W. Holcomb, December 1981. (PB82-177783)
173 Central San Joaquin Valley Type Maps. Thomas R. Crossan, December 1981. (PB82 196064)
174 ARAP Test Results. Mark A. Mathewson, December 1981. (PB82 198103)
Approximations to the Peak Surface Wind Gusts from Desert Thunderstorms. Darryl Randerson, June 1982. (PB82 253089)
Climate of Phoenix, Arizona. Robert J. Schmidli and Austin Jamison, April 1969 (Revised July 1996). (PB96-191614)
178 Annual Data and Verification Tabulation, Eastern North Pacific Tropical Storms and Hurricanes 1982. E.B. Gunther, June 1983. (PB85 106078)
179 Stratified Maximum Temperature Relationships Between Sixteen Zone Stations in Arizona and Respective Key Stations. Ira S. Brenner, June 1983. (PB83 249904)
180 Standard Hydrologic Exchange Format (SHEF) Version I. Phillip A. Pasteris, Vernon C. Bissel, David G. Bennett, August 1983. (PB85 106052)
181 Quantitative and Spacial Distribution of Winter Precipitation along Utah's Wasatch Front. Lawrence B. Dunn, August 1983. (PB85 106912)
182 500 Millibar Sign Frequency Teleconnection Charts - Winter. Lawrence B. Dunn, December 1983. (PB85 106276)
183 500 Millibar Sign Frequency Teleconnection Charts - Spring. Lawrence B. Dunn, January 1984. (PB85 111367)
184 Collection and Use of Lightning Strike Data in the Western U.S. During Summer 1983. Glenn Rasch and Mark Mathewson, February 1984. (PB85 110534)
185 500 Millibar Sign Frequency Teleconnection Charts - Summer. Lawrence B. Dunn, March 1984. (PB85 111359)
186 Annual Data and Verification Tabulation eastern North Pacific Tropical Storms and Hurricanes 1983. E.B. Gunther March 1984. (PB85 109635)
187 500 Millibar Sign Frequency Teleconnection Charts - Fall. Lawrence B. Dunn, May 1984. (PB85-110930)
188 The Use and Interpretation of Isentropic Analyses. Jeffrey L. Anderson, October 1984. (PB85-132694)
189 Annual Data & Verification Tabulation Eastern North Pacific Tropical Storms and Hurricanes 1984. E.B. Gunther and R.L. Cross, April 1985. (PB85 1878887AS)
190 Great Salt Lake Effect Snowfall: Some Notes and An Example. David M. Carpenter, October 1985. (PB86 119153/AS)
191 Large Scale Patterns Associated with Major Freeze Episodes in the Agricultural Southwest. Ronald S. Hamilton and Glenn R. Lussky, December 1985 (PB86 144474AS)
192 NWR Voice Synthesis Project: Phase I. Glen W. Sampson, January 1986. (PB86 145604/AS)
193 The MCC - An Overview and Case Study on Its Impact in the Western United States. Glenn R. Lussky, March 1986. (PB86 170651/AS)
194 Annual Data and Verification Tabulation Eastern North Pacific Tropical Storms and Hurricanes 1985. E.B. Gunther and R.L. Cross, March 1986. (PB86 170941/AS)
195 Radid Interpretation Guidelines. Roger G. Pappas, March 1986. (PB86 177680/AS)
196 A Mesoscale Convective Complex Type Storm over the Desert Southwest. Darryl Randerson, April 1986. (PB86 190998/AS)
197 The Effects of Eastern North Pacific Tropical Cyclones on the Southwestern United States. Walter Smith, August 1986. (PB87 106258AS)
198 Preliminary Lightning Climatology Studies for Idaho. Christopher D. Hill, Carl J. Gorski, and Michael C. Conger, April 1987. (PB87 180196/AS)
Heavy Rains and Flooding in Montana: A Case for Slantwise Convection. Glenn R. Lussky, April 1987. (PB87 185229/AS)
Annual Data and Verification Tabulation Eastern North Pacific Tropical Storms and Hurricanes 1986. Roger L. Cross and Kenneth B. Mielke, September 1987. (PB88 110895/AS)
201 An Inexpensive Solution for the Mass Distribution of Satellite Images. Glen W. Sampson and George Clark, September 1987. (PB88 114038/AS)
202 Annual Data and Verification Tabulation Eastern North Pacific Tropical Storms and Hurricanes 1987. Roger L. Cross and Kenneth B. Mielke, September 1988. (PB88-101935/AS)
203 An Investigation of the 24 September 1986 "Cold Sector" Tornado Outbreak in Northern California. John P. Monteverdi and Scott A. Braun, October 1988. (PB89 121297/AS)
204 Preliminary Analysis of Cloud-To-Ground Lightning in the Vicinity of the Nevada Test Site. Carven Scott, November 1988. (PB89 128649/AS)
205 Forecast Guidelines For Fire Weather and Forecasters -- How Nighttime Humidity Affects Wildland Fuels. David W. Goens, February 1989. (PB89 162549/AS)
206 A Collection of Papers Related to Heavy Precipitation Forecasting. Western Region Headquarters, Scientific Services Division, August 1989. (PB89 230833/AS)
207 The Las Vegas McCarran International Airport Microburst of August 8, 1989. Carven A. Scott, June 1990. (PB90-240268)
208 Meteorological Factors Contributing to the Canyon Creek Fire Blowup, September 6 and 7, 1988. David W. Goens, June 1990. (PB90-245085)
209 Stratus Surge Prediction Along the Central California Coast. Peter Felsch and Woodrow Whitlatch, December 1990. (PB91-129239)
210 Hydrotools. Tom Egger. January 1991. (PB91-151787/AS)
211 A Northern Utah Soaker. Mark E. Struthwolf, February 1991. (PB91-168716)
212 Preliminary Analysis of the San Francisco Rainfall Record: 1849-1990. Jan Null, May 1991. (PB91-208439)
213 Idaho Zone Preformat, Temperature Guidance, and Verification. Mark A. Mollner, July 1991. (PB91-227405/AS)
214 Emergency Operational Meteorological Considerations During an Accidental Release of Hazardous Chemicals. Peter Mueller and Jerry Galt, August 1991. (PB91-235424)
215 WeatherTools. Tom Egger, October 1991. (PB93-184950)
216 Creating MOS Equations for RAWS Stations Using Digital Model Data. Dennis D. Gettman, December 1991. (PB92-131473/AS)
217 Forecasting Heavy Snow Events in Missoula, Montana. Mike Richmond, May 1992. (PB92-196104)
218 NWS Winter Weather Workshop in Portland, Oregon. Various Authors, December 1992. (PB93-146785)
219 A Case Study of the Operational Usefulness of the Sharp Workstation in Forecasting a Mesocyclone-Induced Cold Sector Tornado Event in California. John P. Monteverdi, March 1993. (PB93-178697)
220 Climate of Pendleton, Oregon. Claudia Bell, August 1993. (PB93-227536)
221 Utilization of the Bulk Richardson Number, Helicity and Sounding Modification in the Assessment of the Severe Convective Storms of 3 August 1992. Eric C. Evenson, September 1993. (PB94-131943)
222 Convective and Rotational Parameters Associated with Three Tornado Episodes in Northern and Central California. John P. Monteverdi and John Quadros, September 1993. (PB94-131943)
223 Climate of San Luis Obispo, California. Gary Ryan, February 1994. (PB94-162062)
224 Climate of Wenatchee, Washington. Michael W. McFarland, Roger G. Buckman, and Gregory E. Matzen, March 1994. (PB94-164308)
225 Climate of Santa Barbara, California. Gary Ryan, December 1994. (PB95-173720)
226 Climate of Yakima, Washington. Greg DeVoir, David Hogan, and Jay Neher, December 1994. (PB95-173688)
227 Climate of Kalispell, Montana. Chris Maier, December 1994. (PB95-169488)
228 Forecasting Minimum Temperatures in the Santa Maria Agricultural District. Wilfred Pi and Peter Felsch, December 1994. (PB95-171088)
229 The 10 February 1994 Oroville Tornado--A Case Study. Mike Staudenmaier, Jr., April 1995. (PB95-241873)
230 Santa Ana Winds and the Fire Outbreak of Fall 1993. Ivory Small, June 1995. (PB95-241865)
231 Washington State Tornadoes. Tresté Huse, July 1995. (PB96-107024)
232 Fog Climatology at Spokane, Washington. Paul Frisbie, July 1995. (PB96-106604)
233 Storm Relative Isentropic Motion Associated with Cold Fronts in Northern Utah. Kevin B. Baker, Kathleen A. Hadley, and Lawrence B. Dunn, July 1995. (PB96-106596)
234 Some Climatological and Synoptic Aspects of Severe Weather Development in the Northwestern United States. Eric C. Evenson and Robert H. Johns, October 1995. (PB96-112958)
235 Climate of Las Vegas, Nevada. Paul H. Skrbac and Scott Cordero, December 1995. (PB96-135553)
236 Climate of Astoria, Oregon. Mark A. McInerney, January 1996.
237 The 6 July 1995 Severe Weather Events in the Northwestern United States: Recent Examples of SSWEs. Eric C. Evenson, April 1996.
238 Significant Weather Patterns Affecting West Central Montana. Joe Lester, May 1996. (PB96-178751)
239 Climate of Portland, Oregon. Clinton C. D. Rocky, May 1996. (PB96-17603)
240 Downslop Winds of Santa Barbara, CA. Gary Ryan, July 1996 (PB96-191697)
241 Operational Applications of the Real-time National Lightning Detection Network Data at the NWSO Tucson, AZ. Darren McCollum, David Bright, Jim Meyer, and John Glueck, September 1996. (PB97-108450)
242 Climate of Pocatello, Idaho. Joe Heim, October 1996. (PB97-114540)
243 Climate of Great Falls, Montana. Matt Jackson and D. C. Williamson, December 1996.
244 WSR-88D VAD Wind Profile Data Influenced by Bird Migration over the Southwest United States. Jesus A. Haro, January 1997.

NOAA SCIENTIFIC AND TECHNICAL PUBLICATIONS

The National Oceanic and Atmospheric Administration was established as part of the Department of Commerce on October 3, 1970. The mission responsibilities of NOAA are to assess the socioeconomic impact of natural and technological changes in the environment and to monitor and predict the state of the solid Earth, the oceans and their living resources, the atmosphere, and the space environment of the Earth.

The major components of NOAA regularly produce various types of scientific and technical information in the following kinds of publications.

PROFESSIONAL PAPERS–Important definitive research results, major techniques, and special investigations.

CONTRACT AND GRANT REPORTS–Reports prepared by contractors or grantees under NOAA sponsorship.

ATLAS--Presentation of analyzed data generally in the form of maps showing distribution of rainfall, chemical and physical conditions of oceans and atmosphere, distribution of fishes and marine mammals, ionospheric conditions, etc.

TECHNICAL SERVICE PUBLICATIONS -- Reports containing data, observations, instructions, etc. A partial listing includes data serials; prediction and outlook periodicals; technical manuals, training papers, planning reports, and information serials; and miscellaneous technical publications.

TECHNICAL REPORTS--Journal quality with extensive details, mathematical developments, or data listings.

TECHNICAL MEMORANDUMS--Reports of preliminary, partial, or negative research or technology results, interim instructions, and the like.

Information on availability of NOAA publications can be obtained from:

NATIONAL TECHNICAL INFORMATION SERVICE

U. S. DEPARTMENT OF COMMERCE

5285 PORT ROYAL ROAD

SPRINGFIELD, VA 22161