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THE CLIMATE OF THE H. J. ANDREWS EXPERIMENTAL FOREST AND ITS REGIONAL SYNTHESIS

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ABSTRACT

Multiple regression analysis is used to create a synthetic record of monthly total precipitation (back to 1914) and monthly mean temperature (back to 1890) at the Primary Meteorological site at the H.J. Andrews (HJA) Experimental Forest, Oregon. The synthetic record shows considerable interannual variability both in precipitation and in temperature. The warming of approximately the last two decades is, so far, no greater than a similar warming which took place at the beginning of the century. The recent warming is found not only in minimum temperatures but also in maximum and mean temperatures. It is found in all seasons but is most marked in spring . For the most part it is paralleled by, but is greater than, the warming at Corvallis and Cottage Grove. The drought of the late 1980s and early 1990s was similar in magnitude to that of the mid 1970s and similar in magnitude but not, so far, duration of that of the 1930s. Both the precipitation and the temperature record at the HJA are in general agreement with what is known from other studies of temporal changes in Oregon and the PNW. The HJA record agrees in general with the tree ring record of the larger scale region. There is evidence that a step function at 1976 which has been found in other biophysical time series in the PNW also occurs in HJA precipitation and temperature values. There was no evidence found in these values for a step function centered on 1957. The climate record of the HJA is closely related to that of the Willamette Valley and Northern Cascades climatic divisions of Oregon. Local GCM-related indicies are quite well related to the HJA climate record in winter but not in summer. Hence, we can have some confidence that whatever climatic change is projected by GCMs for the PNW will be applicable in large measure to the HJA Forest in winter and for the winter water year. Since most vegetative growth takes place in the spring and summer months, the ecological implications of this climatic finding should be noted. By the standards usually applied in synoptic climatology there are quite strong relationships between the HJA winter water year precipitation and annual and January mean temperatures and both the PNA and the CNP indicies. No relationships are found for July. The CNP index is a particularly well correlated with January and annual temperatures at the HJA. This is indicative of the importance of the magnitude and position of the Aleutian low pressure cell to the HJA temperatures. There is a weak but definite signal between the SOI (ENSO) index and the climate of the HJA such that during many warm events (El Nino years) the winter water year precipitation at the HJA Forest is relatively low and the annual mean temperatures are relatively high. During cold events (La Nina) the winter water year precipitation at the HJA Forest is relatively high, especially in the winter water year following a calendar year with a cold event, and the annual mean temperatures are relatively low. Overall, it is concluded that the climate of the HJA Forest is well representative of the climate of the northern Cascades and their foothills in particular and of the PNW in general.

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INTRODUCTION

The H.J. Andrews Experimental Forest (HJA) is a 6400 ha forest of Douglas Fir (*Pseudotsuga menziesii* (Mirb.) Franco), Western Hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and Pacific Silver Fir (*Abies amabilis* Doug. ex Forbes) located in, and typical of, the central portion of the western slope of the Cascade mountain range of Oregon. The forest is currently one of 19 sites in the Long-Term Ecological Research (LTER) program sponsored by the National Science Foundation (Franklin et al., 1990). During the 1970s it was a representative site in the Coniferous Forest Biome Project of the U.S. International Biological Program. It was originally established in 1948 as an Experimental Forest of the U.S. Forest Service. There is an immense legacy of research resulting from the participation of the Andrews Forest in these research programs (McKee. et al., 1987, Blinn et al.,1988). Future participation in LTER ensures the continuing scientific importance of the site.

Climatological information has been collected at the site since 1951 with a continuous, electronically sensed, record from May 1972. The observing system is composed of a primary meteorological station and a network of satellite temperature and precipitation recording stations. Because of the large scientific significance of the HJA it is important to investigate the temporal variability of annual and seasonal temperature and precipitation values at the site and identify past times of anomalous climatic conditions. It is also important to establish quantitatively the relationships between the climate of the HJA and that of its surrounding area and hence place the climate of the HJA into its regional context.

Consequently the goals of research reported below are to:

1) produce a long-term (ca 100 year) synthetic record of the climate of the HJA;

2) analyze the long-term record of the HJA in relation to other research in the forest;

3) place the climate of the HJA Forest into its regional context.

The general hypothesis relating to the third objective is that the climate of the HJA Forest is well representative of the climate of the northern Cascades and their foothills in particular and of the PNW in general.

This report will commence with some important background information concerning the HJA and its climate as well as the regional climate of the Pacific Northwest (PNW). The methods of data analysis employed to develop a long-term synthetic climatic record of the HJA will then be described. Next, the synthetic record of monthly mean and annual temperature and monthly mean and annual precipitation will be analyzed and compared with important indicies and values of the regional climate. We find that, in large part, the climate of the HJA is a child of the climatic interactions between the ocean and the atmosphere in the northern Pacific Ocean and even further afield.

BACKGROUND INFORMATION

The Climate of HJA

The primary meteorological station of HJA is at an elevation of 426 m (1397 ft) at latitude 44° 15' N and longitude 122° 10' W (Fig. 1). HJA occupies the Lookout Creek watershed which ranges from 420 to 1630 m (1378 to 5346 ft) and drains into the Blue River. Below 1050m (3444 ft), the Western Hemlock zone is found and is characterized by Western Hemlock and Douglas Fir. Above 1050m (3444 ft) the Pacific Silver Fir zone is established (Bierlmaier and McKee, 1989).

Bierlmaier and McKee (1989) have described the HJA climate as being wet and fairly mild in winter and warm and dry in summer. They emphasize the role of the polar front jet stream in funnelling into the area one low pressure zone and frontal storm after another during the winter. Precipitation comes mainly from cold or occluded fronts. The storms are slowed by the Coast and Cascade ranges and are consequently of long duration and low intensity. The summer season is dominated by the establishment of a ridge of high pressure along the coast and the eastern Pacific. Consequently this season is characterized by highly stable air and low precipitation amounts. During the period 1973 to 1984 the average annual temperature was 8.5° C (47.3° F). Monthly temperatures ranged from 0.6° C (33.1° F) in January to 17.8° C (64.0° F) in July. The annual average precipitation was 2302 mm (90.6 ins) 71% of which fell from November through March. At 1203 m (3946 ft) annual precipitation rises to 2785 mm (109.7 ins). Above 1050 m (3444 ft) a persistent snowpack up to 4 m (13 ft) deep may form and last into June (Bierlmaier and McKee, 1989). Further details of the climatography of HJA may be found in Emmingham and Lundburg (1977 - quoted by (Bierlmaier and McKee, 1989)), Waring et al. (1978), and McKee and Bierlmaier (1987).

The regional climate of Oregon and the PNW and the importance of the Pacific Ocean

Regional ciimatologies of the Oregon and the Pacific Northwest (PNW) often emphasize the role of the synoptic climatic features and the unique topography and geography of the region. Phillips (1960) describes the surface level semi-permanent high and low pressure zones over the Pacific Ocean. In spring and summer circulation around a high pressure cell brings westerly and northwesterly flows to the PNW. In fall and winter, circulation around the Aleutian low pressure zone brings westerly and southwesterly flow. Both summer and winter flows act to keep the climate equable. Any extremes of high or low temperatures are usually associated with relatively rare air flows from the land area of the North American continent. Sternes (1960) highlights the interplay of the synoptic climatology with the north-south aligned Coastal Range and Cascade mountain ranges, the long, 429 mile, coastline of Oregon, and other topographic features such as the Willamette valley and the interior eastern high plateau. Other useful descriptive climatologies and climatographies have been given by the PNW River Basins Commission (1969) and Loy et al., (1976).

The National Weather Service divides the state of Oregon into eight climatic divisions namely: the Coastal area, Willamette Valley, Southwestern Valleys, Northern Cascades, North Central, South Central, Northeast, and Southeast. Somewhat different classifications of regions have been suggested by Jones (1953), Sternes (1960),and Loy et al. (1976) but all investigators agree in general on the major divisions and the spatial heterogeneity of Oregon climate principally associated with topography. The HJA Forest is located in the Northern Cascades division but is also close to the Willamette Valley and Southwestern Valleys divisions.

No understanding of the climate of the PNW would be complete without reference to the seminal role played by interactions between the ocean and atmosphere in the area of the northern Pacific Ocean and, to some degree, the tropical and southern parts of the Pacific as well.

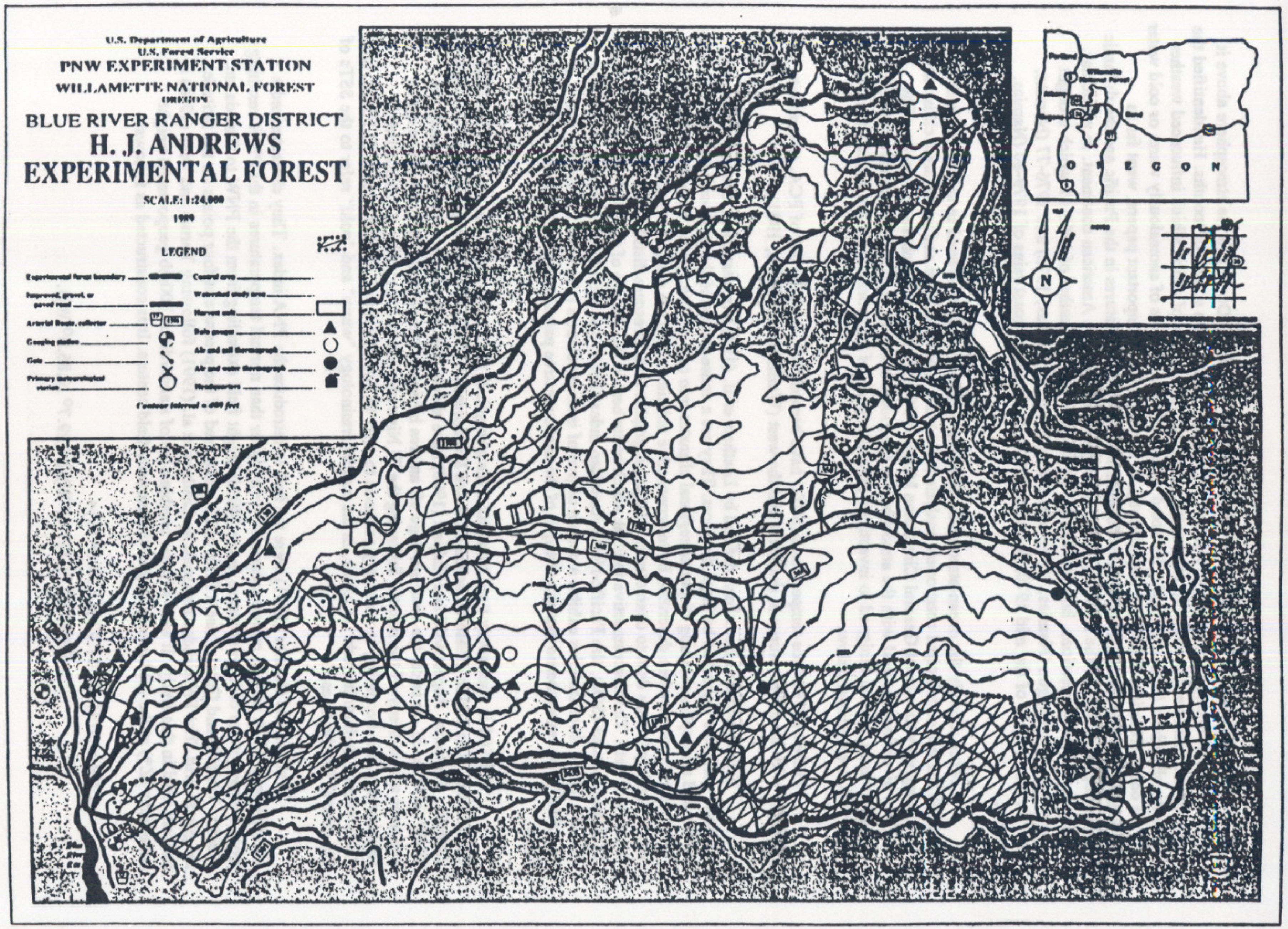


Figure 1—Meteorological installations, H.J. Andrews Experimental Forest, Blue River, Oregon. From Bierlmaier and Mckee, 1989

Namias (1959) was the first to hypothesize that the Pacific Ocean and the atmosphere above it could feed off one another and give rise to a continuity of climate on a scale of months. He identified the area of the Aleutian low pressure zone as being an important center of action which influenced weather systems elsewhere (Namias, 1968). He noted the importance of pools of anomalously warm or cold water in the ocean (Namias, 1969) and subsequently, in a long series of important papers, went far in explaining the detailed interconnections between sea surface temperatures in the Pacific and the dynamic and synoptic climate of the PNW and many other parts of the North American continent. In particular, using these interconnections, he explained the noteworthy winter weather of 1968-69 which brought heavy snows to Oregon (Namias, 1971), and that of 1971-72 (Namias, 1972) and 1976-77 (Namias, 1978), the drought of the mid 1970s (Namias, 1979), and the west coast rains of 1979-80 (Namias, 1981).

More recently the ocean-atmosphere interconnections have been treated in synoptic climatology through the use of principal component analysis (PCA) and teleconnections and in dynamic climatology increasingly by the use of General Circulation Models (GCMs) of the atmosphere and ocean . The GCMs, by definition, deal with the atmosphere at the global scale. PCA and teleconnective studies, on the other hand, can be designed to investigate particular parts of the world and those studies relevant for the PNW are outlined below.

Pacific sea surface temperatures (SSTs) have been shown, with the use of PCA, to correlate strongly with air temperatures in the PNW and the west (Walsh and Richman, 1981).

Teleconnections have been defined by Leathers et al. (1991) as "statistical associations among climatic variables separated by large distances. They are a consequence of the large-scale dynamics of the ocean and atmosphere linking disparate regional climates into one unified, global climatic system". Teleconnections are often described by teleconnective indicies which are designed from observed atmospheric pressure data to characterize a large geographic scale pressure distribution from a small amount of data. The teleconnective indicies which relate best to the climate of the PNW are the Southern Oscillation Index (SOI), the Pacific-North American Index (PNA) and the Central North Pacific Index (CNP). These three indicies exhibit a certain degree of intercorrelation (Cayan and Peterson, 1989). It should also be remembered that the strength of the teleconnective patterns is not necessarily stable over time.

The SOI is commonly used to measure the strength of the El Nino and, the opposite, La Nina, phenomena. The SOI is measured as the mean sea level pressure (MSLP) difference between Tahiti and Darwin, Australia. Ropelewski and Halpert (1986) have shown that depending on the data used, the PNW is either in, or is on the southern edge of, an area having lower rainfalls when El Ninos are in progress and in many of the months following the El Nino maximum. Due partly to difficulties in terminology it is becoming increasingly common to refer to "warm events" (which include El Ninos) and "cold events" (which include La Nina). In the newer terminology "warm" and "cold" refer to the SSTs of the central Pacific Ocean.

Wallace and Gutzler (1981) were the first to introduce the PNA index. They characterized a strong winter PNA pattern as one associated with higher than normal temperatures in the PNW resulting from a strong ridge of high pressure in the 700mb height field extending from the PNW to Canada and Alaska. Wallace and Gutzler use a PNA index comprised of the pressure at four points on the latitude, longitude grid. The PNA index designed by Leathers et al. (1991) following Yarnal and Diaz (1986) is the one used in this study. It uses a linear combination of standardized 700mb geopotential height anomalies (Z^*) at the grid points nearest the anomaly field centers. It is constructed as follows:

$$PNA = 1/3\{-Z^*(47.9^{\circ} N, 170.0^{\circ} W) + Z^*(49.0^{\circ} N, 111.0^{\circ} W) - Z^*(29.7^{\circ} N, 86.3^{\circ} W)\}.$$

The PNA describes the amplitude of the 700mb flow pattern over the U.S. which has a basic pattern of troughs of low pressure in the eastern Pacific and the eastern U.S, and a ridge of high pressure over the Rocky Mountain cordillera (see Leathers et al. 1991. Fig.1). The meridional extreme of the pattern produces positive PNA values (and potentially more SW winds over the HJA) while the zonal extreme produces negative PNA values (and potentially more W winds over the HJA). Yarnal and Diaz (1986) demonstrated how strongly positive PNA and negative (reverse) PNA patterns are associated respectively with warm and cold El Nino Southern Oscillation (ENSO) events and, in turn, with precipitation and temperature anomalies on the west coast of North America.

Cayan and Peterson (1989) designed the CNP index as being the MSLP over the region 35-55° N and 170° E to 150° W. They show that streamflow in the West have correlations in the range 0.3 to 0.6 SLP with anomalies in the North Pacific. During times of a weak CNP streamflows are high in Washington and Oregon. During times of a strong CNP the polar front jet stream flows north of the PNW and times of below average streamflow are observed. This is also often observed during El Nino events (See Cayan and Peterson, 1989, Fig.9).

It has also been shown that there are interrelationships between the values of the SOI, PNA and the CNP indicies (Cayan and Peterson, 1989). Significant correlations appear between the SOI and PNA during winter and spring, the SOI and the CNP during winter, and the PNA and the CNP during winter spring and fall. All of the synoptic studies indicate quite clearly the linkages which exist between SSTs and particular pressure and teleconnective patterns in the Pacific Ocean and various aspects of climate on the West Coast and the in the PNW.

Given this background information it now appropriate to discuss the data used in the present study.

DATA PROCESSING

Data were collected from a variety of sources. They were screened for temporal continuity of the observing station and preprocessed to make them available for analysis. This section describes the data sources, screening, and preprocessing.

Data from the Oregon Climate Service

The Oregon Climate Service, directed by Mr. George Taylor at Oregon State University, provided electronic data for monthly mean temperature and total precipitation for several potentially relevant National Weather Service climate stations in Oregon. Original files were fed into Excel spreadsheets. In the case of temperature, months with incomplete data were assigned the value listed in the original file. Months with missing data were assigned the long term average computed from the whole period of record for that month. The format of values were changed from hundredths of inches to inches with one decimal place. In the case of precipitation, months with traces were assigned 0, and months with missing data were assigned the long term mean. If there were years with many missing data at the early part of the record then the first years of the record were omitted from further analysis. The long term average was used for Eugene for 1915 where the data for the whole year were missing.

The temperature and precipitation record of all nearby stations were examined and that of more distant stations were examined if they had a long record. The NWS stations examined and initially considered were Corvallis, Cottage Grove, Eugene, Leaburg, McKenzie Bridge, Salem, Sisters, Cascadia, Fern Ridge Dam, Lookout Point Dam, and Roseburg. After examining these stations for length and completeness of record it was decided that the stations most likely to give information for the project at hand were Corvallis, Cottage Grove, Eugene, Leaburg, McKenzie Bridge, and Cascadia. The station history of each of these stations was examined for continuity.

Station History

The history of each station used in the analysis was inspected for any changes potentially affecting the values of the observations. Station histories for Oregon are given by Redmond (1985). No major changes during the period of the record were found for Cottage Grove, Leaburg, and Corvallis State University. Potentially important altitudinal changes were noted for Cascadia and McKenzie Bridge and a spatial change was identified for Eugene observations. In the case of Cascadia and McKenzie Bridge, topographic maps were examined to see if the recording site changes might lead to differences in the microclimate. Factors such as influence of cold air drainage or rain gauge exposure were considered in particular. In neither case did these factors appear to present a problem. Consequently no changes were made to the precipitation data and the pre-change temperature data were adjusted using a lapse rate of -7.82^{o}C / km (See section below explaining this). This lapse rate was computed using annual mean temperature values for the area from the stations employed in the analysis for the period 1975-1990 during which there were no locational changes made in any of the stations.

In the case of Eugene there was a change in the recording site, which took place in December 1948, from an area near the city center (at the location of the current Eugene Country Club just north of the Willamette river), to the airport in a rural setting 8 miles north-west from the original recording site. Data before and after this time were tested with a student's t test and regression analysis (comparing to data from Cottage Grove and Corvallis) to see if there was a marked change in the relations between the two sets of climate values. It was found that for mean annual temperature values during the period 1905-1948 and during the complete record (1905-1990) the means from Eugene and Corvallis could come from the same population (confidence level 99 %) but this was unlikely for the period 1949-1990. In all three periods the means for Eugene and Cottage Grove probably came from different populations. The latter was also true for annual precipitation values for all three stations and for all three time periods (all years of record, pre-1949 years, post 1948 years). Regression analysis showed some differences between r^2 values between the stations and the periods (Eugene/Corvallis temperature 1905-48 $r^2 = 0.68$, Eugene/Corvallis temperature 1949-1988 $r^2 = 0.28$, Eugene/Cottage Grove temperature 1931-48 $r^2 = 0.87$, Eugene/Cottage Grove 1949-1990 $r^2 = 0.42$, Eugene/Corvallis precipitation 1905-1948 $r^2 = 0.10$, Eugene/Corvallis precipitation 1949-1988 $r^2 = 0.01$, Eugene/Cottage Grove precipitation 1916-1948 $r^2 = 0.88$, Eugene/Cottage Grove 1949-1990 $r^2 = 0.90$). The poor correlation between Eugene and Corvallis annual precipitation and good correlation between Eugene and Cottage Grove in the same variable is interesting. Overall the data are somewhat equivocal concerning whether the Eugene record may be used as a coherent one in its two temporal parts. Consequently it was decided not to use the Eugene record.

Lapse Rates

As noted above, it was necessary to apply a temperature lapse rate (LR) to the temperature values of two of the stations used in the analysis. A literature search was performed to determine an appropriate lapse rate value. Barry (1992) suggests that an average lapse rate for mountain environments is -6.0^{o} C / km but that there is a variation with an upper limit in the dry adiabatic lapse rate (DALR) of -9.8^{o} deg C/km. The saturated or moist adiabatic lapse rate (SALR) when the air temperature is greater than 20^{o} C is greater than -5^{o} C/km. At -40^{o} C the SALR almost equals the DALR. Barry (1992, p45) notes that spatial variation of lapse rates "render the practice of adjusting average station temperatures...to sea level likely to produce ... misleading results". Further (p329) he states that for maritime air on the coast of NW Europe lapse rates are steep (because of maritime air mass characteristics). Typically they might be -8.5^{o} C /km for annual mean max temperature, -6 to -7^{o} C /km for winter minimum temperatures, and -8 to -10^{o} C/km for spring maximum temperatures. The mean and maximum temperature LRs in Britain in winter are closely similar. Woodward (1987) cites a typical LR for Europe as being -6.7° C/km while Oliver and Fairbridge (1987, p541) quote a general value of -5° C /km.

Given the uncertainty described above and the presence in the western PNW of both complex topography and frequent conditions giving rise to the application of the SALR, it seemed that the most appropriate approach is to actually calculate the "characteristic" west slope mean annual temperature lapse rate from actual Oregon data. This was done using annual mean temperature and altitude data for Corvallis, Eugene, Cottage Grove, Cascadia, and McKenzie Bridge for 1975 - 1990. The resulting the lapse rate was -7.82°C / km which is consistent with above information. This lapse rate is still rather steep but is comparable to those quoted by Barry for NW Europe. Since characteristic LRs are used frequently in ecological studies it would be appropriate to employ actual data from the PNW to investigate this topic further.

Data from H.J. Andrews Experimental Forest

Data from the HJA Forest were provided by Mr. Don Henshaw from the Long-Term Ecological Research section of the Forest Science Data Bank in the Forest Sciences Laboratory at Corvallis. The data files were reformatted from their original sequential format into tables of values by month and year. Precipitation data for the primary meteorological site for the years 1973-1978 were taken from Bierlmaier and McKee (1989).

Other Data Sources

Mr. George Taylor of the Oregon Climate Service provided data for the Willamette Valley and Northern Cascade climate divisions of Oregon and most SOI values. Supplementary SOI values were provided by Dr. R. Cerveny, of the Department of Geography at Arizona State University. PNA values were provided by Dr. D. Leathers, of the Department of Geography at the University of Delaware.

COMPILATION OF THE SYNTHETIC RECORD

Regression Analysis

Multiple regression analysis was used in order to find the monthly values of mean temperature and total precipitation at the HJA from values at the stations which had been selected resulting from the screening procedures described above. The analysis was performed within Excel spreadsheets. Two limitations of this kind of multiple regression analysis should be noted. First, the analysis by least squares causes synthetic extreme values to be moved towards the long term mean of the data set. Thus extreme values in the synthetic data series noted before 1973 might well be more extreme than presented here. Second, it is assumed that the relationships found for the period 1973-1991 apply equally well to the period before 1973. This may not be so but, in the absence of real data, can not be tested. It is encouraging to note, however, that the strength of the relationship between HJA precipitation and temperature values and the value of the Central North Pacific index is approximately the same when tested on one set of data between 1948 and 1987 and a set , which includes the first, between 1910 and 1990 (see Table 20). The same multiple regression function was used to produce all correlation coefficients in this report and reports the correlation coefficient values as positive irrespective of whether they are positive or negative.

Precipitation

Precipitation data for the HJA site was obtained from five stations; Corvallis, Leaburg, McKenzie Bridge, Cascadia, and Cottage Grove. The multiple regression analysis identified good correlation in monthly and annual precipitation values between the stations. It also identified some low correlations which, with the use of scattergrams, were found to be due to mis-entered data for Cascadia.

The data were corrected and the analysis for the appropriate months was performed again. All regression equations were significant at the 99% level as assessed by their F values. There is, of course, considerable intercorrelation among the values at the five stations. Regression equations were computed for different sets of stations for three separate time periods which were determined by the length of record of the stations. The time periods were 1936-1972, 1919-1935, and 1910-1918. Tables 1, 2, and 3 show the computed regression equations for these time periods along with their respective r^2 and standard error of estimate (SEE) values. When the regression equations indicated precipitation values less than zero during dry summer months, a zero value was inserted for that month. A separate test was made to see if the annual totals were more accurately obtained from the sum of the regression values for each month or from the regression equation for annual totals. It was found that when annual values from the sum of the individual months of regressed data were regressed against the actual values for the period 1973-91 the r^2 value was 0.96 (SEE 3.23 ins). This compared to an r^2 value of 0.93 (SEE 4.30 ins) when annual values were regressed against actual annual values for the same time period. It was concluded that it was more accurate to use the sum of the 12 monthly totals for the annual total value for the earlier years. Nevertheless the regression equation derived from the annual totals is provided for convenience of future workers. Precipitation data for the year 1927 were missing for both Corvallis and Cascadia so for this year the regression is made against Cottage Grove data only (Table. 4).

A similar analysis was performed for precipitation values in the form of water year data. Following Johnson and Dart (1982) the water year is defined as the period October 1 to the next September 30 and the year is numbered for the year which includes the 9 month period. So the 1940 water year runs from October 1, 1939 to September 30, 1940. The analysis was also performed for the winter part of the water year (October to April) and the summer (May to September). The selection of seasons this way also follows the approach of Johnson and Dart (1982) and has obvious practical and hydrological advantages. Regressions were computed in a manner which paralleled that described for the 12 months as described above. The only exception was that since the summer water year regressions had the least accuracy, as measured by their r^2 value, in the final data tabulation the summer value for HJA is computed as the whole water year value minus the winter water year value. All the relevant regression equations and their accuracy parameters are added to Tables 1-4. As might be expected the water year and winter water year correlations carry a higher degree of accuracy than those for the calendar year. Johnson and Dart (1982, pp104-111) provide maps of seasonal and monthly correlation coefficients between precipitation at Corvallis and the rest of the state of Oregon. The values found in the present report are of the same order and are consistent with the findings of Dart and Johnston.

Table 1. Regression equations for obtaining monthly total precipitation (in inches) at the H. J. Andrews Primary Meteorological Site from precipitation values at other stations for the period 1936-1972. Co is Corvallis, L is Leaburg, M is McKenzie Bridge, Ca is Cascadia, CG is Cottage Grove, SEE is the standard error of estimate of the equation, CalYr is the Calendar Year, WatYr is the Water Year, WWY is the winter water year (Oct-April), SWY is the summer water year (May-Sept).

Month	Equation	r^2	SEE
Jan	A= -(0.25*Co)+(0.54*L)+(0.20*M)+(0.83*Ca)+(0.25*CG)-0.25	0.92	1.81
Feb	A= (0.20*Co)+(0.30*L)+(0.28*M)+(0.78*Ca)-(0.04*CG)+0.53	0.94	1.41
Mar	A= (0.77*Co)+(0.72*L)+(0.96*M)-(0.29*Ca)-(0.71*CG)+0.02	0.93	1.17
April	A= (0.67*Co)+(0.66*L)+(0.30*M)+(0.31*Ca)-(0.51*CG)-0.55	0.89	0.89
May	A= (0.22*Co)+(0.03*L)+(0.55*M)+(0.09*Ca)+(0.22*CG)+0.65	0.92	0.61
June	A= (0.44*Co)+(0.12*L)+(0.47*M)+(0.05*Ca)+(0.51*CG)-0.33	0.98	0.34
July	A= (0.11*Co)+(0.04*L)+(0.53*M)+(0.03*Ca)-(0.03*CG)+0.19	0.88	0.30
Aug	A= -(0.39*Co)+(0.49*L)+(0.11*M)+(0.28*Ca)+(0.24*CG)-0.01	0.93	0.47
Sept	A= -(0.06*Co)+(0.80*L)+(0.90*M)-(0.39*Ca)-(0.14*CG)-0.26	0.97	0.59
Oct	A= (0.17*Co)+(0.51*L)+(0.68*M)+(0.52*Ca)-(0.79*CG)+0.12	0.93	1.31
Nov	A= (0.03*Co)+(0.24*L)+(0.81*M)+(0.10*Ca)+(0.36*CG)-0.35	0.98	1.19
Dec	A= (0.32*Co)-(0.48*L)+(0.72*M)+(0.52*Ca)+(0.60*CG)-0.37	0.97	1.58
CalYr	A= (0.04*Co)+(0.10*L)+(0.42*M)+(0.40*Ca)+(0.97*CG)-16.72	0.93	4.91
WatYr	A=(-0.02*Co)-(0.21*L)+(0.42*M)+(0.45*Ca)+(1.13*CG)-6.21	0.98	3.22
WWY	A=(-0.21*Co)-(0.81*L)+(0.50*M)+(0.77*Ca)+(1.57*CG)-0.35	0.99	2.50
SWY	A=(-0.06*Co)+(0.39*L)+(0.44*M)+(0.09*Ca)+(0.34*CG)-0.63	0.87	1.48

Table 2. Regression equations for obtaining monthly total precipitation (in inches) at the H. J. Andrews Primary Meteorological Site from precipitation values at other stations for the period 1919-1935. Co is Corvallis, Ca is Cascadia, CG is Cottage Grove, SEE is the standard error of estimate of the equation, CalYr is the Calendar Year, WatYr is the Water Year, WWY is the winter water year (Oct-April), SWY is the summer water year (May-Sept).

Month	Equation	r^2	SEE
Jan	A= -(0.30*Co)+(1.27*Ca)+(0.74*CG)-0.04	0.92	1.72
Feb	A= (0.60*Co)+(1.45*Ca)-(0.15*CG)+0.89	0.92	1.44
Mar	A= (0.42*Co)+(1.11*Ca)-(0.02*CG)+0.27	0.82	1.74
April	A= (0.59*Co)+(0.87*Ca)-(0.04*CG)+0.09	0.84	1.01
May	A= (0.23*Co)+(0.48*Ca)+(0.35*CG)+0.82	0.86	0.79
June	A= (0.05*Co)+(0.74*Ca)+(0.56*CG)-0.30	0.94	0.48
July	A= -(0.06*Co)+(0.38*Ca)+(0.42*CG)+0.25	0.83	0.33
Aug	A= (0.06*Co)+(0.61*Ca)+(0.46*CG)+0.00	0.90	0.50
Sept	A= (0.27*Co)+(0.97*Ca)+(0.49*CG)-0.59	0.91	0.97
Oct	A= (0.29*Co)+(1.08*Ca)+(0.04*CG)+0.13	0.90	1.41
Nov	A= -(0.20*Co)+(0.92*Ca)+(0.90*CG)+0.02	0.93	1.92
Dec	A= (0.47*Co)+(0.84*Ca)+(0.51*CG)-0.54	0.94	2.12
CalYr	A= (0.02*Co)+(0.65*Ca)+(1.50*CG)-20.29	0.91	5.28
WatYr	A= (-0.02*Co)+(0.78*Ca)+(1.03*CG)-8.27	0.96	3.76
WWY	A= (-0.11*Co)+(0.87*Ca)+(1.03*CG)-4.19	0.97	3.49
SWY	A= (0.22*Co)+(0.58*Ca)+(0.51*CG)+0.06	0.82	1.65

Table 3. Regression equations for obtaining monthly total precipitation (in inches) at the H. J. Andrews Primary Meteorological Site from precipitation values Corvallis (Co) for the period 1910-1918. SEE is the standard error of estimate of the equation, CalYr is the Calendar Year, WatYr is the Water Year, WWY is the winter water year (Oct-April), SWY is the summer water year (May-Sept).

Month	Equation	r^2	SEE
Jan	A= (1.52*Co)+3.28	0.64	3.44
Feb	A= (1.68*Co)+2.39	0.83	1.96
Mar	A= (1.58*Co)+2.72	0.63	2.37
April	A= (1.43*Co)+2.45	0.47	1.74
May	A= (1.48*Co)+1.27	0.74	1.02
June	A= (1.72*Co)+0.36	0.83	0.79
July	A= (0.80*Co)+0.30	0.67	0.43
Aug	A= (1.17*Co)+0.42	0.59	0.96
Sept	A= (1.91*Co)+0.19	0.67	1.72
Oct	A= (1.83*Co)+0.90	0.70	2.30
Nov	A= (1.45*Co)+4.77	0.78	3.26
Dec	A= (1.85*Co)+0.63	0.86	2.97
CalYr	A= (1.55*Co)+21.91	0.61	10.05
WatYr	A= (1.52*Co)+22.70	0.77	8.43
WWY	A= (1.53*Co)+19.75	0.80	8.20
SWY	A= (1.39*Co)+3.27	0.65	2.16

Table 4. Regression equations for obtaining monthly total precipitation (in inches) at the H. J. Andrews Primary Meteorological Site from precipitation values at Cottage Grove (CG) for 1927. SEE is the standard error of estimate of the equation, CalYr is the Calendar Year, WatYr is the Water Year, WWY is the winter water year (Oct-April), SWY is the summer water year (May-Sept).

Month	Equation	r^2	SEE
Jan	A= (1.92*CG)+1.06	0.78	2.72
Feb	A= (1.51*CG)+3.31	0.83	2.01
Mar	A= (1.27*CG)+3.05	0.51	2.74
April	A= (1.03*CG)+2.40	0.45	1.77
May	A= (1.19*CG)+1.26	0.73	1.03
June	A= (2.10*CG)-0.01	0.76	0.91
July	A= (0.78*CG)+0.36	0.70	0.41
Aug	A= (1.12*CG)+0.39	0.73	0.79
Sept	A= (1.96*CG)-0.04	0.83	1.23
Oct	A= (1.95*CG)-0.24	0.82	1.77
Nov	A= (1.59*CG)+2.69	0.85	2.64
Dec	A= (1.76*CG)+2.02	0.88	2.71
CalYr	A= (1.97*CG)-1.46	0.78	7.28
WatYr	A= (1.83*CG)+4.69	0.92	5.00
WWY	A= (1.81*CG)+6.01	0.93	4.77
SWY	A= (1.56*CG)+1.20	0.60	2.31

Temperature

The same five predictor stations employed for estimating precipitation values were investigated using their average annual data between 1973 and 1991 for their efficiency in simulating temperature values. Correlation coefficient, SEE, and significance values between the five stations and the Andrews data (Table 5) indicate that the data from Cascadia had a detrimental effect on the strength of the regression equations. It was therefore decided to omit data from Cascadia for the rest of the analysis. The strength of the relationships between the stations is noteworthy for the fact that the relationship between Andrews and Corvallis is as strong or stronger than any other relationship between Andrews and individual or groups of stations. It is difficult to explain this fact since Corvallis is the most distant station. It is consistent however with the fact that temperature data from stations in areas of complex terrain can be quite variable due to local conditions. Individual monthly regressions (Tables 6, 7, and 8) display the expected results in which higher correlations are found with the use of four stations, two stations, and then the single Corvallis station. Based on these considerations monthly values of regression equations were computed for Andrews using the regression equations in Tables 6 through 8 for the appropriate sets of years. All equations are significant at the 99.9% confidence level with the exception of Table 5 Oct (99.0%), Cal Yr(95.0%) and Table 7 CalYr (99.0%).

Table 5. r^2, standard error of estimate, and significance (%) values between annual average temperature values (1973-1991) between data from the H. J. Andrews Primary Meteorological Site and other selected stations. Co is Corvallis, L is Leaburg, M is McKenzie Bridge, Ca is Cascadia, CG is Cottage Grove, SEE is the standard error of estimate of the equation.

	r^2	SEE ^oF	Significance %
Co,L,M,Ca,CG	0.53	1.03	<95
Co,L,M,CG	0.50	1.02	95
Co,L,CG	0.49	0.99	95
Co,M,CG	0.50	0.98	95
Co,CG	0.49	0.96	99
Co	0.49	0.93	99.9
L	0.32	1.07	95
M	0.37	1.03	99
Ca	0.12	1.17	<95
CG	0.34	1.06	99

Table 6. Regression equations for obtaining monthly mean temperature (°F) at the H. J. Andrews Primary Meteorological Site from precipitation values at other stations for the period 1936-1972. Co is Corvallis, L is Leaburg, M is McKenzie Bridge, CG is Cottage Grove, SEE is the standard error of estimate of the equation, CalYr is the Calendar Year.

Month	Equation	r^2	SEE
Jan	A=(0.14*Co)+(1.18*L)+(0.40*M)-(0.57*CG)-11.10	0.83	1.51
Feb	A= -(0.25*Co)+(1.65*L)-(0.69*M)+(0.48*CG)-17.94	0.88	1.41
Mar	A= (0.34*Co)+(1.02*L)-(0.15*M)-(0.08*CG)-12.42	0.87	1.22
April	A= (0.01*Co)+(0.86*L)+(0.22*M)+(0.14*CG)-15.26	0.88	1.27
May	A= (0.42*Co)+(0.55*L)+(0.19*M)-(0.08*CG)-7.29	0.79	1.11
June	A= -(0.39*Co)+(0.42*L)+(0.78*M)+(0.01*CG)+7.23	0.80	1.18
July	A= (0.34*Co)+(0.02*L)-(0.04*M)+(0.59*CG)+4.25	0.74	1.05
Aug	A= -(0.43*Co)+(1.36*L)+(0.06*M)+(0.35*CG)-24.72	0.92	0.84
Sept	A= (0.32*Co)+(0.56*L)+(0.08*M)-(0.09*CG)+1.90	0.74	1.36
Oct	A= (0.06*Co)+(0.98*L)-(0.33*M))-(0.01*CG)+8.86	0.69	1.30
Nov	A= (0.44*Co)+(0.70*L)-(0.33*M)+(0.02*CG)-6.76	0.78	1.83
Dec	A= -(0.05*Co)+(0.90*L)+(0.23*M)-(0.15*CG)-2.70	0.75	1.62
CalYr	A= (1.06*Co)-(0.08*L)-(0.04*M)+(0.20*CG)-12.20	0.50	1.02

Table 7. Regression equations for obtaining monthly mean temperature (°F) at the H. J. Andrews Primary Meteorological Site from precipitation values at other stations for the period 1917-1935. Co is Corvallis, CG is Cottage Grove, SEE is the standard error of estimate of the equation, CalYr is the Calendar Year.

Month	Equation	r^2	SEE
Jan	A=(0.38*Co)+(0.53*CG)-2.66	0.73	0.73
Feb	A=(0.54*Co)+(0.61*CG)-13.27	0.82	1.64
Mar	A=(0.91*Co)+(0.30*CG)-15.49	0.84	1.25
April	A=(0.81*Co)+(0.49*CG)-19.29	0.84	1.39
May	A=(0.91*Co)+(0.37*CG)-17.84	0.77	1.09
June	A=(0.71*Co)+(0.18*CG)+4.84	0.60	1.57
July	A=(0.38*Co)+(0.52*CG)+5.04	0.73	0.99
Aug	A=(0.76*Co)+(0.49*CG)-18.46	0.84	1.11
Sept	A=(0.79*Co)+(0.15*CG)-2.04	0.71	1.35
Oct	A=(0.52*Co)+(0.28*CG)+5.07	0.57	1.43
Nov	A=(0.71*Co)+(0.39*CG)-10.62	0.76	1.80
Dec	A=(0.13*Co)+(0.61*CG)+4.21	0.65	1.79
CalYr	A=(1.23*Co)-(0.12*CG)-10.85	0.49	0.96

Table 8. Regression equations for obtaining monthly mean temperature (^{o}F) at the H. J. Andrews Primary Meteorological Site from precipitation values at Corvallis (Co) for the period 1910-1918.

Month	Equation	r^2	SEE
Jan	A= (0.89*Co)-1.71	0.65	1.97
Feb	A= (1.14*Co)-12.48	0.80	1.67
Mar	A= (1.19*Co)-14.88	0.84	1.24
April	A= (1.28*Co)-18.36	0.82	1.42
May	A= (1.16*Co)-11.51	0.76	1.09
June	A= (0.85*Co)+6.91	0.60	1.53
July	A= (0.84*Co)+8.40	0.68	1.06
Aug	A= (1.17*Co)-14.50	0.79	1.22
Sept	A= (0.93*Co)-1.37	0.71	1.31
Oct	A= (0.76*Co)+6.88	0.56	1.40
Nov	A= (1.08*Co)-9.94	0.75	1.79
Dec	A= (0.67*Co)+7.31	0.62	1.80
CalYr	A= (1.14*Co)-11.78	0.49	0.93

Verification

If the HJA primary meteorological station record had been longer it would have been possible to withhold some data from the regression analysis for use in later verification. However this was not possible, and in its absence, the values of the SEE of the regressions are the best available information for assessment of the accuracy of the simulated data. Examination of the interannual variation in the simulated data shows that almost always, year to year values of both precipitation and temperature vary far more than the SEEs of the relevant regression equations.

Further limited verification analysis may be performed by virtue of the fact that data exist for Watershed #2 starting from 1952 for precipitation and from 1959 for temperature. Monthly mean values of these data were correlated with the simulated (1952 or 59 to 1972) record and the observed (1973 to 84 or 90) Primary Meteorological Station record. The length of correlation period for the observed record varied by month due to missing data from Watershed #2 especially in the case of precipitation. The correlation analysis (Tables 9 and 10) indicates that the simulated data are generally closely correlated with the observed data between the Primary Site and the Watershed #2 site. This is particularly true when the two sets of observed data at the two sites are correlated. In some months the simulated data show an even higher correlation than that between the two sets of observed data. The correlation between the temperatures observed at the two sites between 1973 and 1990 is quite low in some months which suggests that significant differences in microclimate exist at the two sites.

Overall it may be concluded that the simulated temperature and precipitation series have an accuracy level which certainly justifies further temporal and spatial analysis of the data.

Table 9. Correlation coefficients between monthly total precipitation at the H. J. Andrews Primary Meteorological Site and the H.J. Andrews Watershed #2 Site

Month	Simulated 1952-1972 r^2	Observed 1973-1983/90 r^2
Jan	0.87	0.85
Feb	0.85	0.99
Mar	0.90	0.99
April	0.79	0.98
May	0.95	1.00
June	0.75	1.00
July	0.74	1.00
Aug	0.94	1.00
Sept	0.91	1.00
Oct	0.97	1.00
Nov	0.97	1.00
Dec	0.94	1.00
CalYr	0.93	0.98
Winter Wat Yr	0.84	0.47

Table 10. Correlation coefficients between monthly mean temperature at the H. J. Andrews Primary Meteorological Site and the H.J. Andrews Watershed #2 Site

Month	Simulated 1959-1972 r^2	Observed 1973-1983/90 r^2
Jan	0.55	0.83
Feb	0.88	0.82
Mar	0.70	0.78
April	0.85	0.75
May	0.90	0.36
June	0.81	0.77
July	0.72	0.46
Aug	0.76	0.83
Sept	0.92	0.71
Oct	0.73	0.25
Nov	0.87	0.58
Dec	0.94	0.73
CalYr	0.68	0.48*

*** value for period 1976-1990**

ANALYSIS OF THE SYNTHETIC AND OBSERVED RECORD

Precipitation

The above regression equations (Tables 1-4) were used to produce a simulated and observed set of monthly and annual precipitation values, their long-term means and standard deviations, for the HJA Forest (Appendix 1) for the period 1910-1991 (continuous from 1913). The values were also rearranged to provide water year (October to September) and winter water year (October to April) data (Appendix 1).

The precipitation record from 1911 to 1991, as represented by the total annual precipitation by water year (Fig. 2) displays considerable interannual variability.

The trends represented by the five year running mean of the same data (Fig. 3) plainly show the prolonged and severe drought of the 1930s and the wetter years of the late 1940s and the 1950s. In more recent years, the record exhibits greater variability with two peaks of precipitation centered on 1973 and 1984 with droughts centered on the late 1970s and one which persisted through, at least, 1991. In the case of both the most recent drought and that of the 1970s, as judged by the value of water year precipitation, both were as severe as the drought of the 1930s but at least the 1970s drought did not last so long.

The variations of precipitation at the HJA described above match quite well trends in the Willamette Valley described by Johnson and Dart (1982). Johnson and Dart also note, for western Oregon, high interannual variability and correspondingly, relatively few groupings of wet or dry years.

Temperature

The regression equations for temperature (Tables 6-8) were used to produce a simulated and observed set of monthly and annual mean temperature values and their long-term means and standard deviations for the HJA Forest (Appendix 2) for the period 1890-1991. The precipitation and temperature data are also provided digitally on a diskette in ASCII format following the appendices.

The annual mean temperature record for the HJA from 1890-1991 (Fig. 4) also shows considerable interannual variability. Analysis of the record in terms of five year running means (Fig. 5) displays a warming trend between the beginning of the record and the early 1940s punctuated by two cool periods in the early 1910s and the early 1920s respectively. A cool period is seen from the late 1940s to the mid 1970s with the exception of one warm year (1958). Finally, a warming trend is seen from the mid 1970s to the present time. However, the magnitude of this trend, at least up to 1991, is similar to that of the warming trend at the beginning of the century.

In analyzing the climatic fluctuations over the Western U.S., Bradley (1982) notes that 1921-35 stand out as anomalously warm in the context of the last 100 years. The HJA data do show high temperatures during this time. 8 of the 15 years of this period at HJA have above (1890-1991) mean temperatures with 3 of the years exceeding the mean by 1 standard deviation (SD). A comparison of individual years of high and low temperatures for Oregon as a whole identified by Bradley is not easily possible in the absence of Bradley's data in a tabular form. Roden (1989) examined data from West Coastal stations. A comparison of low and high temperature winters for these stations (Tables 11 and 12) shows that more often than not the HJA values parallel the coastal values.

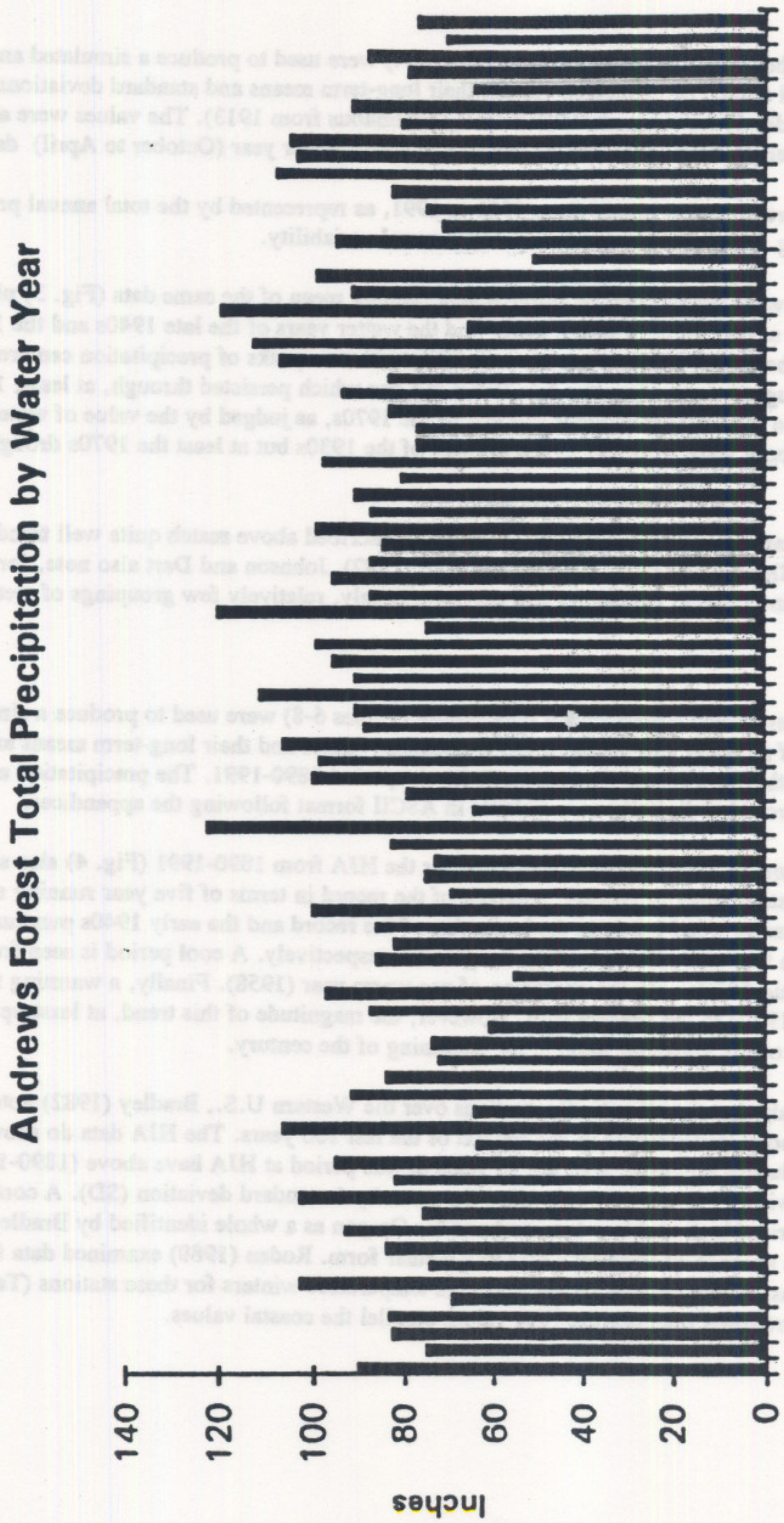


Fig. 2. Total water year precipitation at the H. J. Andrews Experimental Forest.

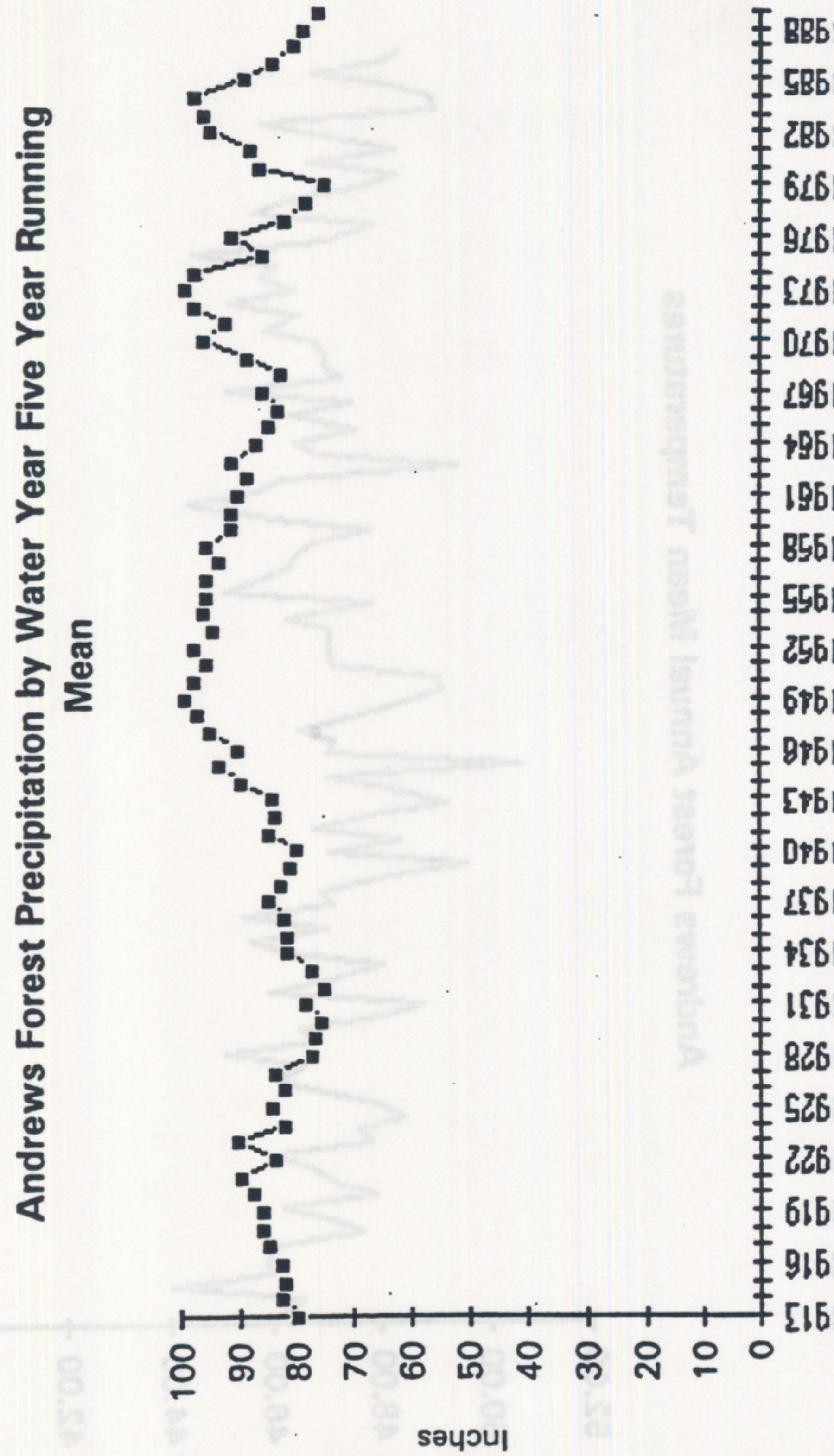


Fig. 3. Five year running mean values of total water year precipitation at the H. J. Andrews Experimental Forest.

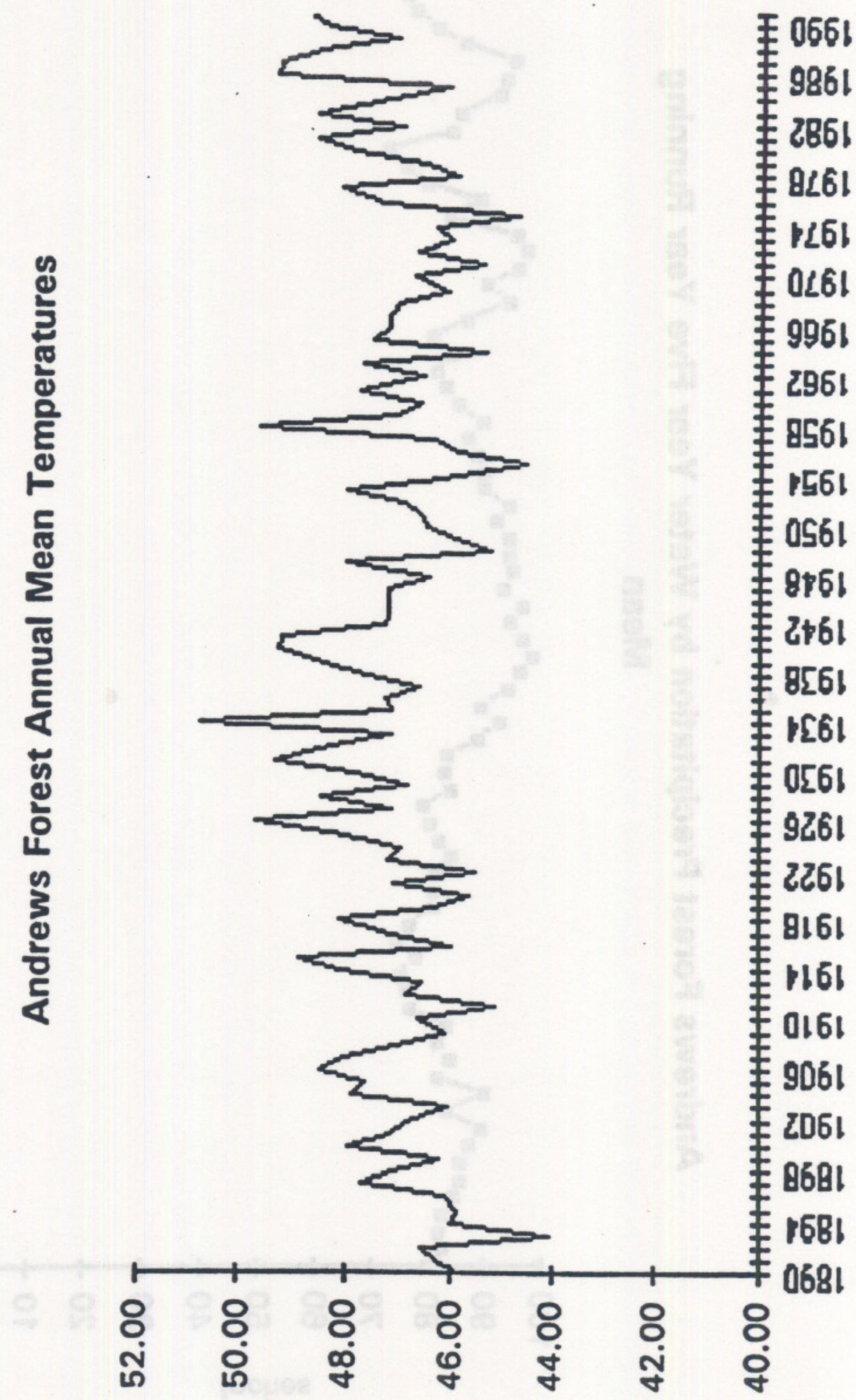


Fig. 4. Annual mean temperatures at the H. J. Andrews Experimental Forest.

Fig 5. Five year running means of annual mean temperatures at the H. J. Andrews Experimental Forest.

Table 11. Comparison of low temperature periods at the HJA (January temperatures, 1890-1991) and coastal values from Roden (1989). The following symbols are used for the HJA comparisons: BM = Below Mean, > 1SD = greater than one standard deviation.

Roden (1989) cold winters 1937 (HJA BM > 1SD), 1950 (HJA BM > 1SD), 1957 (HJA BM > 1SD), 1969 (HJA BM > 1SD)

Roden (1989) cold periods 1948-1956 (HJA 7 of the 9 yrs BM, 3 < 1SD)

Roden (1989) negative anomalies at Brookings and Astoria 1955 (HJA BM)

Table 12. Comparison of high temperature periods at the HJA (January temperatures, 1890-1991) and coastal values from Roden (1989). The following symbols are used for the HJA comparisons: AM = Above Mean, > 1SD = greater than one standard deviation.

Roden (1989) warm winters 1926 (HJA AB), 1931 (HJA AB > 1SD), 1941 (HJA AB > 1SD), 1958 (HJA AB > 1SD), 1983 (HJA AB > 1SD)

Roden (1989) warm periods 1940-1945 (HJA 4 of the 6 yrs AM, 2 > 1SD), 1977-84 (4 of the 8 yrs AM, 3 > 1SD)

Roden (1989) positive anomalies at Brookings 1957 (HJA not positively anomalous) and 1958 (HJA AM >1SD) and Astoria 1958 (HJA AM > 1SD)

Given the current concern regarding global climatic warming it is worth examining the recent warming in the HJA record in more detail.

Recent Warming

Since there has been considerable evidence of a trend for minimum temperatures to increase over the last two to three decades (Karl et al. 1988) the observed HJA record was examined to see if it contained this signal. Maximum, minimum, and mean seasonal and annual temperatures were regressed against year number for the period 1973-1991. The results (Tables 13 and 14, Fig. 6) show that the period had not only increasing minimum temperatures but increasing maximum and mean temperatures as well. Of ecological importance is the fact that the greatest increases occurred in the spring (March, April, May) possibly affecting growth rates at this time. The warming is also seen at Corvallis and Cottage Grove (Table 15) although in not quite as an intense form and not during the winter season. It is important to reiterate that the magnitude of this recent warming trend is similar to one that took place at HJA at the beginning of the century (Fig. 5).

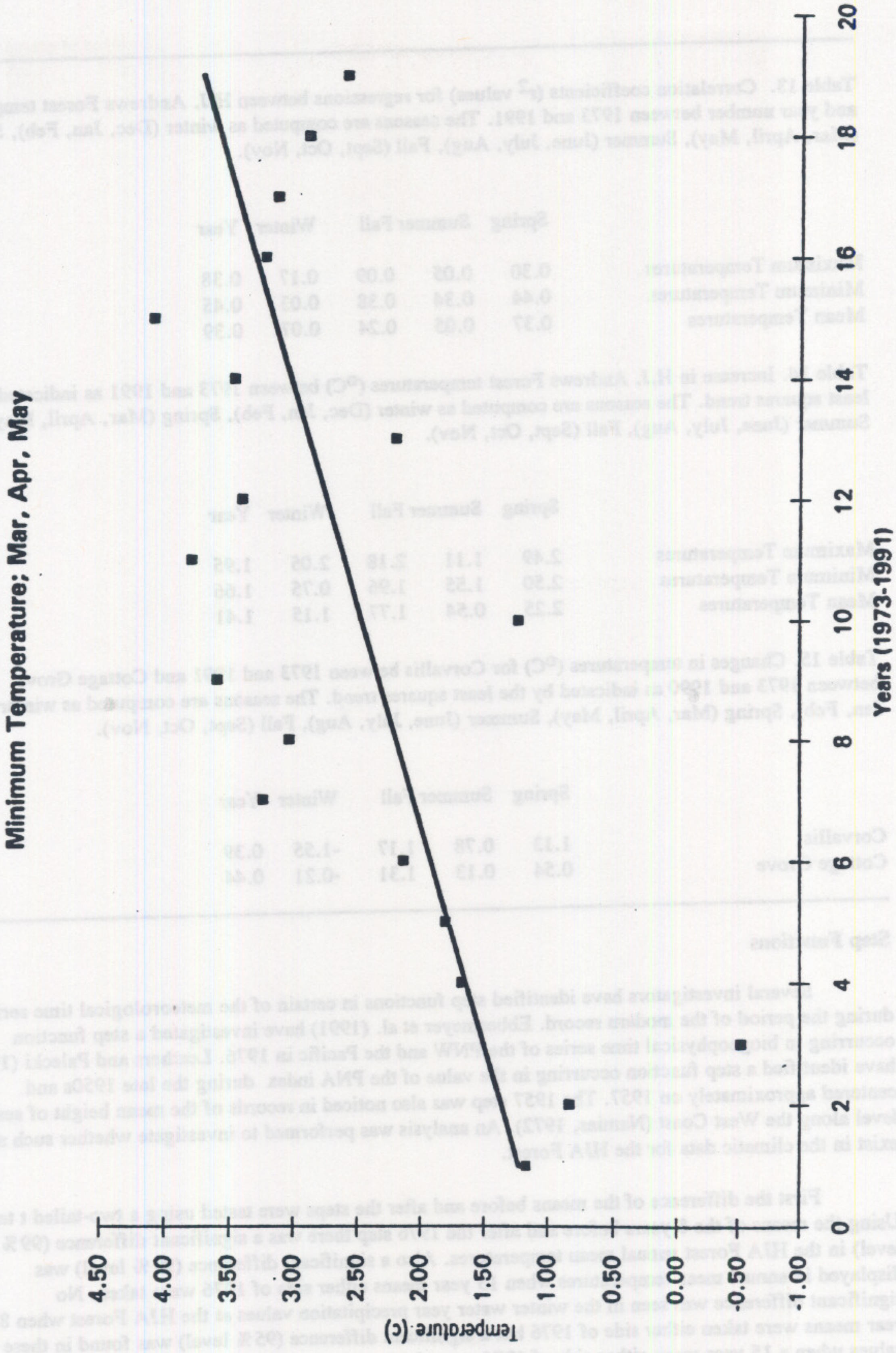


Fig. 6. Average monthly minimum temperatures for March, April, and May between 1973 (Year 1) and 1991 (Year 19) at the H. J. Andrews Experimental Forest.

Table 13. Correlation coefficients (r^2 values) for regressions between H.J. Andrews Forest temperatures and year number between 1973 and 1991. The seasons are computed as winter (Dec, Jan, Feb), Spring (Mar, April, May), Summer (June, July, Aug), Fall (Sept, Oct, Nov).

	Spring	Summer	Fall	Winter	Year
Maximum Temperatures	0.30	0.05	0.09	0.17	0.38
Minimum Temperatures	0.44	0.34	0.38	0.03	0.45
Mean Temperatures	0.37	0.05	0.24	0.07	0.39

Table 14. Increase in H.J. Andrews Forest temperatures (^{O}C) between 1973 and 1991 as indicated by the least squares trend. The seasons are computed as winter (Dec, Jan, Feb), Spring (Mar, April, May), Summer (June, July, Aug), Fall (Sept, Oct, Nov).

	Spring	Summer	Fall	Winter	Year
Maximum Temperatures	2.49	1.11	2.18	2.05	1.95
Minimum Temperatures	2.50	1.55	1.96	0.75	1.66
Mean Temperatures	2.25	0.54	1.77	1.15	1.41

Table 15. Changes in temperatures (^{O}C) for Corvallis between 1973 and 1991 and Cottage Grove between 1973 and 1990 as indicated by the least squares trend. The seasons are computed as winter (Dec, Jan, Feb), Spring (Mar, April, May), Summer (June, July, Aug), Fall (Sept, Oct, Nov).

	Spring	Summer	Fall	Winter	Year
Corvallis	1.13	0.78	1.17	-1.55	0.39
Cottage Grove	0.54	0.13	1.31	-0.21	0.44

Step Functions

Several investigators have identified step functions in certain of the meteorological time series during the period of the modern record. Ebbesmeyer et al. (1991) have investigated a step function occurring in biogeophysical time series of the PNW and the Pacific in 1976. Leathers and Palecki (1992) have identified a step function occurring in the value of the PNA index during the late 1950s and centered approximately on 1957. The 1957 step was also noticed in records of the mean height of sea level along the West Coast (Namias, 1972). An analysis was performed to investigate whether such steps exist in the climatic data for the HJA Forest.

First the difference of the means before and after the steps were tested using a two-tailed t test. Using the means of the 8 years before and after the 1976 step there was a significant difference (99% level) in the HJA Forest annual mean temperatures. Also a significant difference (99% level) was displayed in annual mean temperatures when 15 year means either side of 1976 were taken. No significant difference was seen in the winter water year precipitation values at the HJA Forest when 8 year means were taken either side of 1976 but a significant difference (95% level) was found in these values when a 15 year mean either side of 1976 was taken.

No significant differences were found in HJA Forest annual mean temperatures or winter water year precipitations between 18 year means or 8 year means either side of 1957. At first this result seems hard to explain since there is a weak relationship between the PNA values and HJA precipitation and temperature values (Table 20). However, the relationship is seen more in winter values rather than annual values. Perhaps more important is the fact that Leathers and Palecki (1992) show that the 1957 PNA step is seen most clearly in the S.E. United States center of action of the PNA index rather than either of the two centers closer to the PNW.

Thus it may be concluded that there is evidence in the HJA Forest record for the 1976 step but not for the PNA-related 1957 step.

However we interpret the Andrews record in terms of pre and post 1976 values Figs. 3 and 5 clearly show that the year 1976 was a marked turning point at the HJA for both temperature and precipitation. For approximately 15 years prior to 1976 the annual temperature trend had been downward. Since that time the annual temperature trend has been upwards. In absolute terms the 1977 water year (which includes the winter of 1976-77) had the lowest precipitation values in the entire record with generally higher values both before 1977 and after it. The five year running mean of these data places the turning point two years later.

Clearly the atmosphere changed to a different mode of operation in the mid 1970s and this change is well represented in the HJA data as well as that of many other parts of the PNW.

The Tree Ring Record

Graumlich (1987) using ring width data identified 1973 and 1929 as being severe single year drought events affecting the PNW as a whole. At HJA the annual total and the water year total for 1929 were below the 1914-91 mean but not by more than one SD. 8 of the individual months of this year were below the mean and February, May, September, and November showed more than one SD below the mean. However, the winter water year total was only 29 th lowest in the 76 year period 1915-1991. During 1973 the first 8 months have below mean precipitation totals with three having more than one SD below. Also the winter water year total is more than one SD below the long term mean and is the 3rd lowest in the 76 year period 1914-1991.

The general temporal variation which Graumlich finds for the present century in her defined Western Lowlands and Columbia Basin (but not the Southern Valleys) divisions is similar to the HJA precipitation record. The findings for the HJA are generally consistent with those of Graumlich and tend to suggest that her findings for earlier years back to 1640 would also be applicable to the Andrews. More confidence should be attributed to runs of dry, and presumably wet, years rather than for individual years. One reason for this is the masking of extreme values in the simulated HJA data which is related to the least squares analysis methodology as discussed above. Graumlich finds marked droughts occurring in the Columbia Basin around 1680, and in the 1750s, 1780s, 1790s, 1840s, 1865-1895, and in the 1920s and 1930s. Wet periods occurred from 1695-1715, 1740-1760, and 1810-1835. The wet and dry periods were similar in the Western Lowlands except that the duration of droughts was less. Hatton (1989) found similar results from a tree ring record at Lost Forest located in the eastern end of the Fort Rock Basin in Lake County, Oregon.

Graumlich and Brubaker (1986) analyzed a tree ring record for Longmire, Washington, and commented that the temperatures between 1900 and 1940 were higher than any other extended 40 year period. HJA temperature data for the present century also display high temperatures during this time and thus give rise to the implication that earlier "warm" periods found in the Washington record also occur at the HJA Forest. These warm periods occurred between 1655-1670, 1690-1695, and 1825-1830. "Cool" periods in the Longmire record occurred between 1610-1630, 1640-1650, 1695-1760, 1800-1808, 1840-1850, and 1875-1895.

Other tree ring studies exist such as the report from the "Second North American Dendrochronological Fieldweek", which was held at the HJA. However most of these reports do not provide data in a manner which is easily comparable with the present study.

THE REGIONAL CONTEXT

The next task is to investigate the degree to which the climate values synthesized and observed at the HJA Forest are related to, and representative of, the local and regional area, as well as the degree to which the climate of the HJA is imbedded in the general circulation of the atmosphere on a larger scale. This investigation proceeds by examining the relationships between the HJA climate values and those of nearby climate divisions, local general circulation surface pressure indicies, and the larger teleconnective indicies of the PNA, CNP, and SOI.

Climate Divisional Data

The synthetic and observed precipitation data for the HJA site for the period 1915 to 1991 were compared by correlation techniques on a month by month and annual basis with precipitation data from the Willamette Valley (OR2) and the Northern Cascades (OR4) Oregon Climate Divisions. In this analysis there exists a slight degree of autocorrelation since data from some of the stations in the divisions were used to simulate part of the HJA data set. However, the autocorrelation is very small as Cascadia, Corvallis, Cottage Grove, and Leaburg are just 4 of the 33 stations in the Willamette Valley Division and McKenzie Bridge is just one of eight stations in the Northern Cascades Divisions. Consequently it is reasonable to assume that the small amount of autocorrelation does not markedly affect the results from this analysis.

For precipitation, the relevant r^2 values (Table 16) indicate a strong relation between the HJA site and both the Willamette Valley and the Northern Cascades divisional data. Correlation coefficient values range from 0.60 to 0.92. It is remarkable that high values are found even for the summer months. On the basis of these values the precipitation at the Andrews is slightly more related to the Northern Cascades division (in which it is located) but the high r^2 values indicate it is representative of the area covered by both divisions.

Table 16. r^2 values for correlation between precipitation at the H.J.Andrews Forest and precipitation in the Willamette Valley (OR2) and the Northern Cascades (OR4) Oregon Climate Divisions.

Month	Willamette Division	Northern Cascades Division	Both Divisions
Jan	0.86	0.85	0.88
Feb	0.84	0.85	0.87
Mar	0.78	0.84	0.86
April	0.78	0.77	0.81
May	0.84	0.87	0.89
June	0.85	0.82	0.86
July	0.69	0.75	0.75
Aug	0.81	0.86	0.86
Sept	0.60	0.64	0.65
Oct	0.85	0.92	0.92
Nov	0.88	0.90	0.90
Dec	0.79	0.89	0.90
Cal Year	0.75	0.78	0.80

Given the high correlation values in Table 16, it might be possible to use the divisional data to extend the HJA precipitation record back to 1895. This has not been done here because the divisional data are not consistent over time in the stations used to prepare the data. Nevertheless the high correlation values will mean that the Northern Cascade divisional data would provide a good proxy for the Andrew's precipitation between 1895 and 1915.

The correlation coefficients between the temperature values of the climatic divisions and the HJA Forest (Table 17) are slightly lower than those for precipitation. In most cases the Willamette Valley division has the higher correlation values. This may be due to the high degree of variation of temperature values in complex terrain associated with the wide variety of different microclimates.

Table 17. r^2 values for correlation between mean temperature at the H.J.Andrews Forest and mean temperature in the Willamette Valley (OR2) and the Northern Cascades (OR4) Oregon Climate Divisions.

Month	Willamette Division	Northern Cascades Division	Both Divisions
Jan	0.81	0.86	0.86
Feb	0.85	0.77	0.85
Mar	0.83	0.79	0.84
April	0.87	0.76	0.87
May	0.87	0.72	0.87
June	0.59	0.59	0.63
July	0.78	0.73	0.79
Aug	0.74	0.69	0.76
Sept	0.77	0.73	0.81
Oct	0.66	0.65	0.69
Nov	0.80	0.50	0.80
Dec	0.73	0.67	0.75
Cal Year	0.64	0.56	0.69

General Circulation Indicies

One of the pressing problems in recent research in climate dynamics has been that of attempting to estimate regional values of projected climate change from the projected values at grid points on the coarse network of points used by current GCMs. Wigley et al. (1990) and Jones (1991) performed a study that is singularly relevant to the current investigation in an attempt to address this question. Jones used two sets of predictor variables which could be derived from GCM output and found the values of their correlation coefficients to surface temperature and precipitation values in Oregon. The first set of predictors were MSLP values at 45°N, 120°W, which is approximately at the center of Oregon, a zonal index composed of the pressure difference between 50°N, 120°W and 40°N, 120°W, and a meridional index composed of the pressure difference between 45°N, 130°W and 45°N, 110°W. A second set of predictors were taken as the 700mb pressures at the same locations. With these predictors, acting in concert, Jones was able to explain between 70% and 90% of the spatial variance January and July temperatures, and between 50% and 80% of the spatial variance of January precipitation values, and 40%

to 70% of the spatial variance for July precipitation for large parts of Oregon (Figs.7,8, 9, and 10). Exceptional areas which displayed low variance explanation included the coast and Coast Range for July temperatures and south eastern mountains, plains, and interior basin for precipitation in both January and July.

It is not to be expected that an individual station would show such high correlations. Nevertheless information about the relation of the HJA climate to similar general circulation indicies was thought to be revealing. Consequently, the simulated HJA data were compared with general circulation indicies designed to relate to the PNW region. The indicies were constructed for use with a data set of reconstructed monthly MSLP developed by Jones et al. (1987). The data for North America is on a 5° latitude by 10° longitude grid. Following the approach by Jones (1991) three general circulation indicies were developed. The first was simply a pressure index, (SLP) at 45°N 120°W, a location which happens to be in the center of Oregon and not too far from the HJA. The second was a zonal index comprised of the difference in SLP between 40°N 120°W and 50°N 120°W. Positive values of this index indicate the general strength of westerly winds. The third index was a meridional index comprised of the difference in SLP between 45°N 120°W and 45°N 130°W. Positive values of this index indicate the general strength of southerly winds. These points differ somewhat from those employed in Jones' original study. In order to clarify the regression analysis, the value of the first index was modified by subtracting 1014 mb from each value.

Table 18. Correlation coefficient values between annual mean temperature and winter water year precipitation totals at the HJA and selected general circulation indicies.

Winter water year precipitation 1914-1980

Variable Regressed Against	r^2	Significance Level %
Central Oregon Pressure	0.24	99
Zonal Index	0.15	99
Meridional Index	0.03	<95

Annual mean temperature 1890-1980

Variable Regressed Against	r^2	Significance Level %
Central Oregon Pressure	0.01	<95
Zonal Index	0.01	<95
Meridional Index	0.36	99

The correlation coefficients for the temporally aggregated data (Table 18) indicate a slight correlation between the Central Oregon SLP and winter water year precipitation and between the meridional index and annual mean temperature, where southerly winds are expectedly associated with higher temperatures, but no other relationships are apparent. On the monthly time scale there is greater correlation of HJA temperature and precipitation values and the circulation indicies in January but no correlation in July (Table 19). This is to be expected given the more vigorous general circulation in the

JANUARY TEMPERATURE

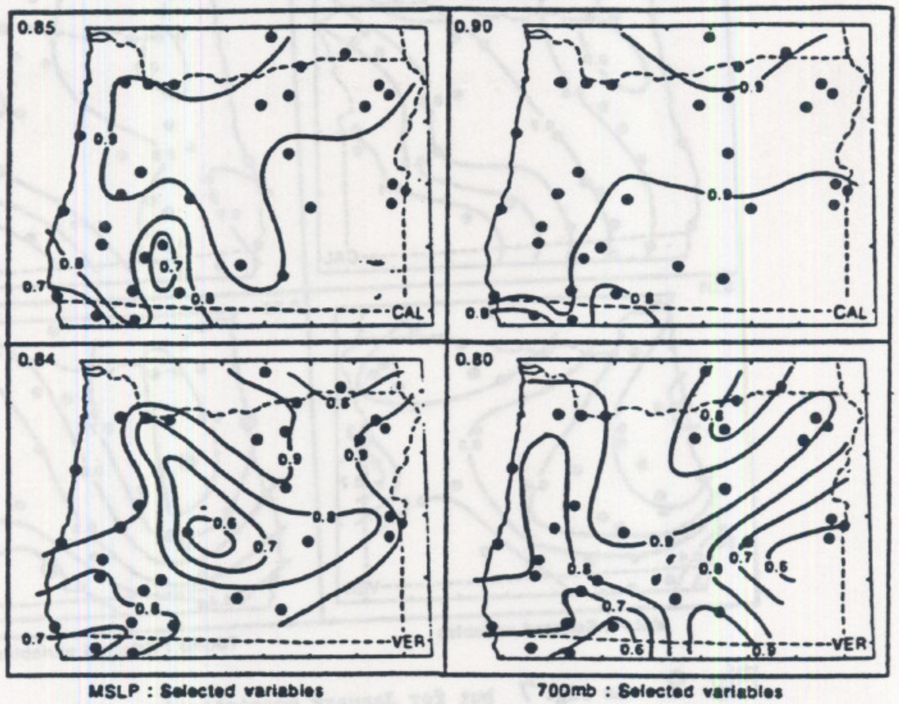


Fig. 7 Spatial pattern of explained variance in calibration (upper maps) and verification (lower maps) for January temperature as the predictand. The left-hand maps show results for the selected subset of predictors from set A (involving MSLP data), while the right-hand maps show results for the selected subset from predictor set B (involving 700hPa heights). Figures in the top left-hand corners give mean explained variances.

JULY TEMPERATURE

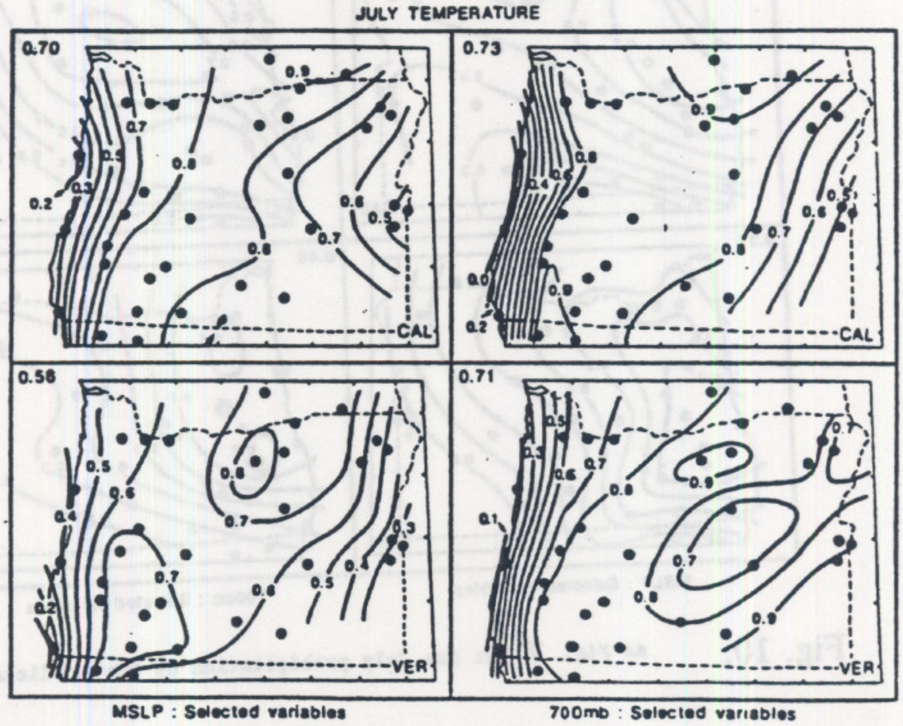


Fig. 8. As Fig. 7 but for July temperature as the predictand.

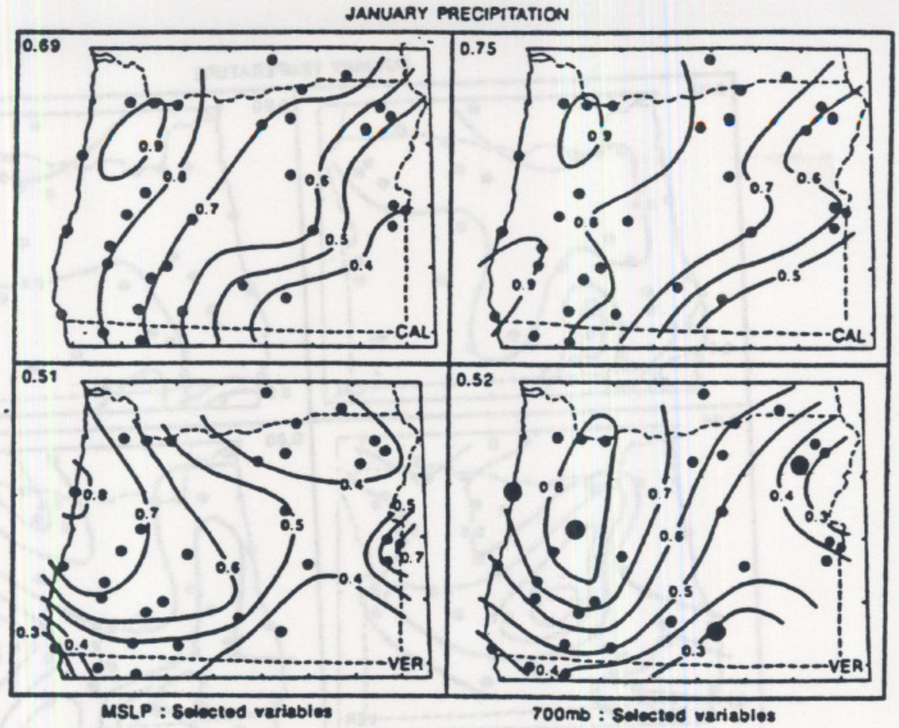


Fig. 9. As Fig. 7 but for January precipitation as the predictand.

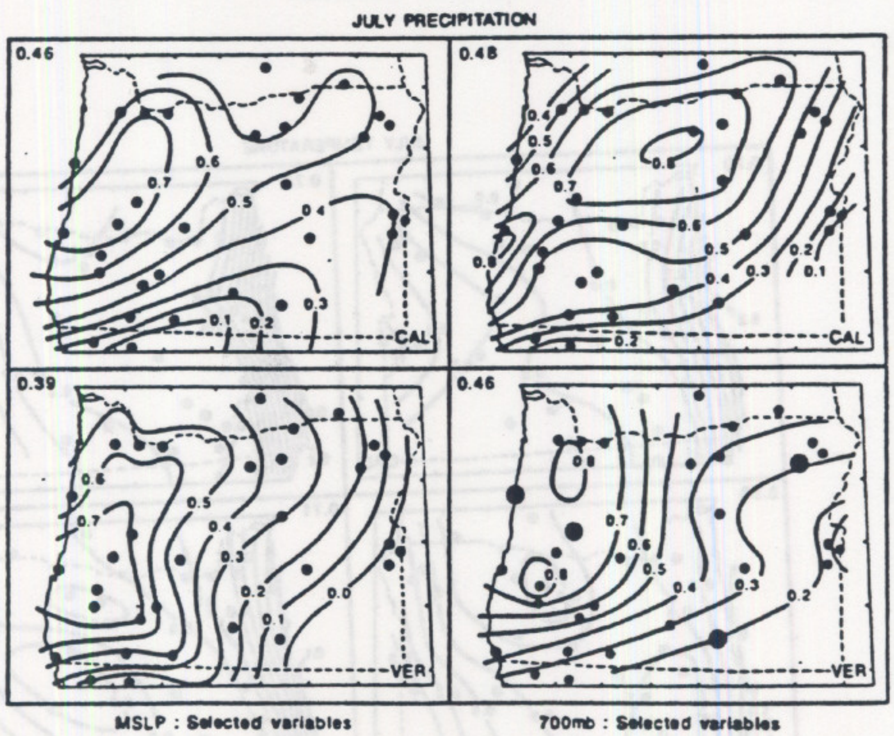


Fig. 10. As Fig. 7 but for July precipitation as the predictand.

Figs. 7 through 10 are from Jones, 1991.

Northern hemisphere winter and the low absolute amount of precipitation at the HJA in summer. In order to be more consistent with Jones' analysis, all three circulation indicators were used together in a multiple regression for January and July. This analysis yielded correlation coefficients of 0.56 (January temperature) and 0.52 (January precipitation) which is comparable to Jones' findings and 0.04 (July temperature) and 0.19 (July precipitation) which is much lower than Jones found for the general location of the HJA. In summary the relationships in winter are much stronger than those in summer. The implication of these results is that output values predicted by GCMs for the general area of the PNW may be applied to the HJA with more confidence in the winter season than in summer.

Table 19. Correlation coefficient values between January and July mean temperature and precipitation totals at the HJA and selected general circulation indicies for the period 1914-1980.

Precipitation	Jan		July	
Variable Regressed Against	r^2	Sig Level %	r^2	Sig Level %
Central Oregon Pressure	0.29	99	0.03	<95
Zonal Index	0.22	99	0.04	<95
Meridional Index	0.07	95	0.04	<95
All three indicies	0.52	99	0.19	99

Temperature	Jan		July	
Variable Regressed Against	r^2	Sig Level %	r^2	Sig Level %
Central Oregon Pressure	0.32	95	0.00	<95
Zonal Index	0.32	99	0.04	<95
Meridional Index	0.28	99	0.00	<95
All three indicies	0.56	99	0.04	<95

PNA and CNP Indicies

Correlations were also made between the HJA data and the PNA and the CNP indicies (described in the introductory section) for the period 1948-87. The results (Table 20) indicate quite marked correlations between HJA winter water year precipitation and both indicies. Precipitation at the HJA for January, representing the winter months, also displays a weak but significant correlation with both indicies. No relationships are seen for July, representing the summer months or for the calendar year totals of precipitation. Annual and January mean values of temperature exhibit and very strong correlation with the CNP index. The relationship of January mean temperatures to the PNA index is also very strong while the relationships for the year and for July are not so strong but are significant. Redmond and Koch (1991) also found significant relationships between concurrent precipitation and temperature values in the PNW and PNA values with temperature having the strongest relationship.

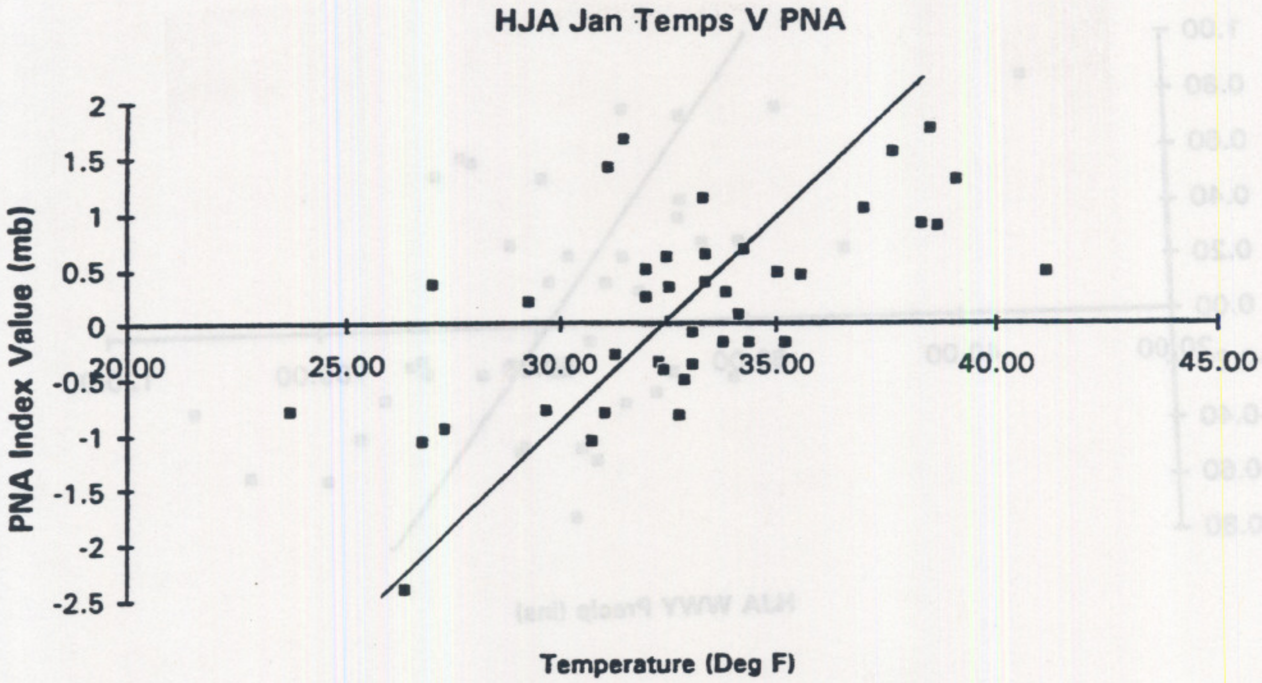
Table 20. Correlation coefficient values between Annual, January and July mean temperature and precipitation totals at the HJA and selected general circulation indicies for the period 1948-1987.

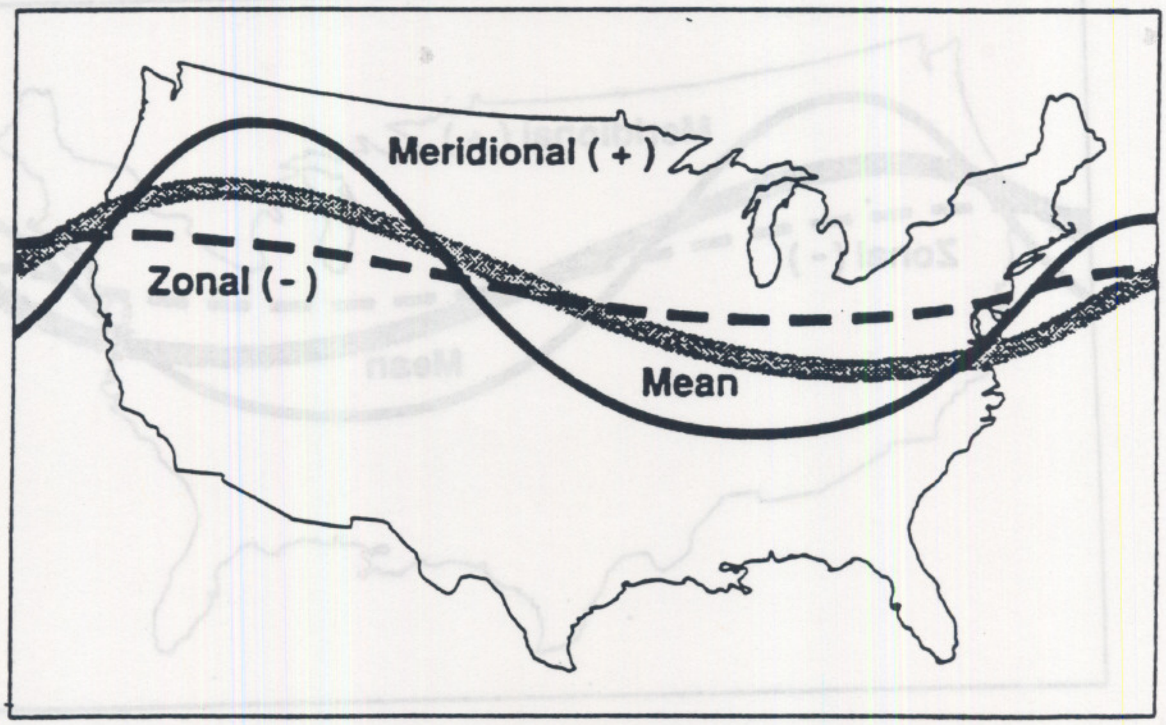
Precipitation		Annual or Winter Water Yr.		Jan		July	
Variable Regressed Against		r^2	Sig Level %	r^2	Sig Level %	r^2	Sig Level %
PNA	Annual	0.08	<95				
	Winter Water Yr.	0.25	99				
PNA				0.16	95	0.00	<95
CNP	Annual	0.04	<95				
	Winter Water Yr.	0.17	99				
CNP				0.10	95	0.06	<95
CNP	Annual (1914-1990)	0.03	<95				
	Winter Water Yr. (1914-90)	0.21	99				
CNP	(1914-1990)			0.11	99	0.03	<95

Temperature	Annual		Jan		July	
Variable Regressed Against	r^2	Sig Level %	r^2	Sig Level %	r^2	Sig Level %
PNA	0.12	95	0.40	99	0.11	95
CNP	0.45	99	0.40	99	0.04	<95
CNP (1910-1990)	0.44	99	0.31	99	0.05	95

The physical significance of these relationships is made quite clear by reference to Figs. 11 and 12 which pair the scattergram of the relationships with the conceptualization by Leathers et al. (1991) of the meaning of the PNA index. When the PNA index is positive and high, a meridional circulation with a ridge of high pressure shunts storms to the north of Oregon (and the HJA) giving rise to relatively dry weather (Fig. 11). This situation also brings in warm air with relatively high temperatures from the southwest (Fig 12). When the PNA index is negative, the zonal circulation brings in storms from the Pacific Ocean giving rise to wetter weather and rather lower air temperatures. These interpretations are also consistent with the CNP values which when low indicate that a well developed Aleutian low pressure zone will guide storms northwards to British Columbia but when high will allow storms to travel more directly eastwards into Washington and Oregon.

The advantage of using the CNP is that it has a long record dating back to 1899. Comparison of the relationships between HJA data and the CNP index for the longer periods of 1910 or 1914 to 1990 (Table 20) indicates little difference in the correlation coefficients that were found for the shorter 1948-

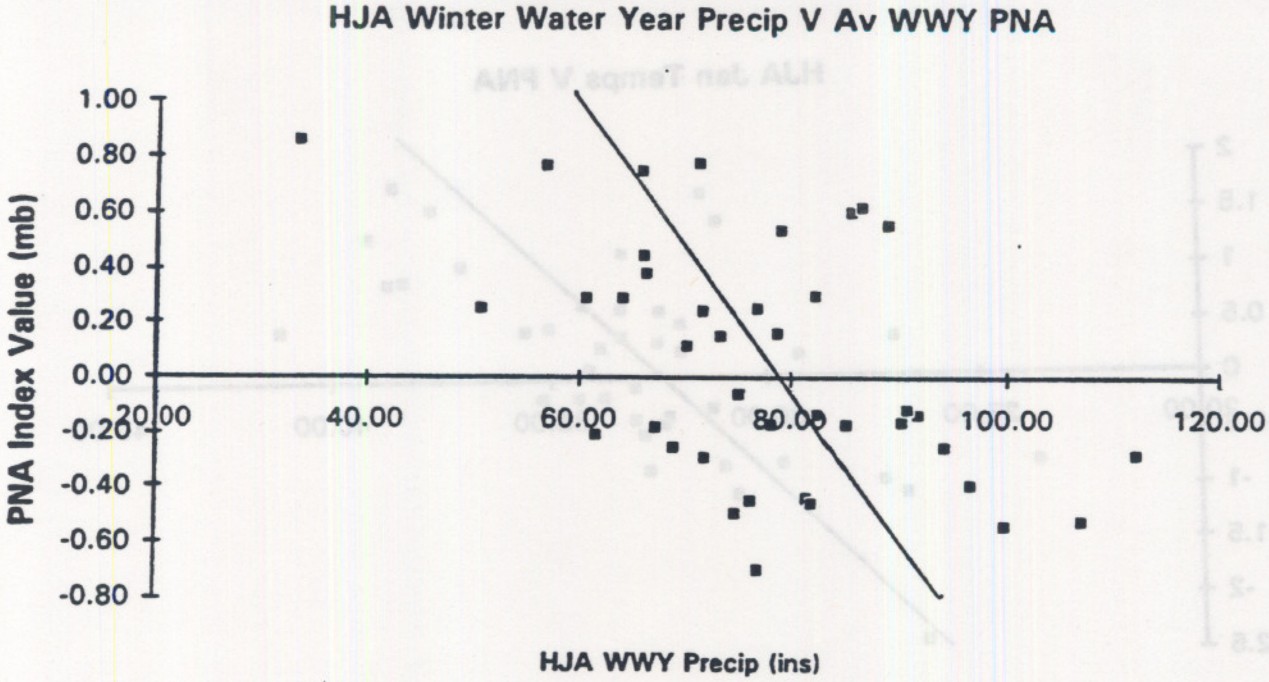


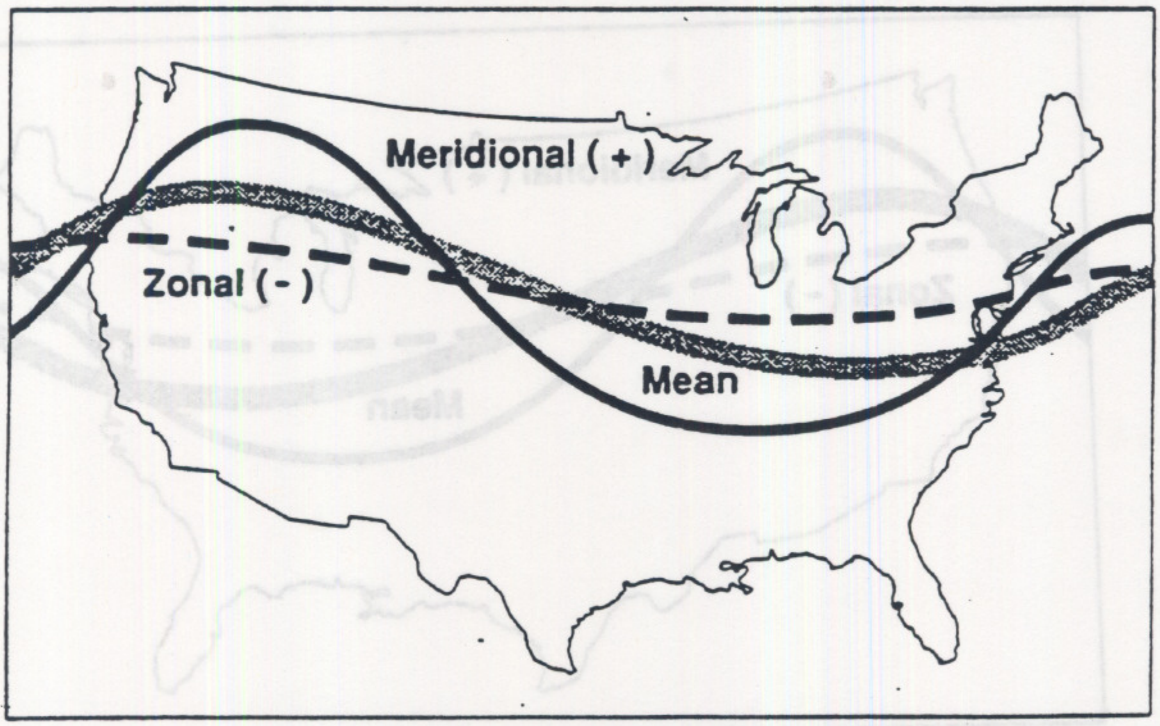


Character of 700-mb flow over the United States for positive and negative values of the PNA index.

From Leathers et al. 1991.

Fig. 11. (Top) Values of winter water year precipitation and the concurrent PNA index value at the H. J. Andrews Experimental Forest. (Bottom) A conceptualization of the 700 mb air flow corresponding to positive and negative PNA values.





Character of 700-mb flow over the United States for positive and negative values of the PNA index.
From Leathers et al. 1991.

Fig. 12. (Top) Values of mean temperatures in January and the concurrent PNA index value at the H. J. Andrews Experimental Forest. (Bottom) A conceptualization of the 700 mb air flow corresponding to positive and negative PNA values.

1990 period. This is encouraging because it suggests that the relationships are fairly stable over time and the time series are relatively stationary.

SOI Index

The winter water year HJA values were compared to temporally corresponding SOI values. The SOI values were transformed so as to be more manageable for statistical and graphical analysis. Each SOI value had 3.0 added to it to make all values positive and, in the case of the precipitation comparison, the resulting values were multiplied by 10 to make them of the same order as the precipitation values. A plot of the two sets of values from 1934 (Fig. 13) indicate some SOI-related signal being apparent in the Andrews winter water year values with low precipitation totals corresponding to El Nino (low transformed SOI value years). The opposite is also true and may be even more marked i.e. La Nina years tend to correspond with high precipitation totals at Andrews. The 1983 year which had an extraordinary strong low SOI value is a noteworthy exception. Direct comparison of winter water year HJA values and transformed SOI values (Fig. 14) indicates the strength of the relationship. The scattergram shows that it is a clear relationship although it is not very strong statistically. (With the 1983 year y=0.18*wwyppt + 15.03 r^2=0.14, significant at 99%, without the 1983 value y=0.20*wwyppt + 13.88, r^2 = 0.23 significant at 99%).

A similar, though stronger and reverse, relationship exists on an annual time scale between the modified SOI values and the annual mean temperature at the HJA Forest (With the 1983 data point r^2=0.24, significant at 99%) (Fig.15). In the case the SOI values were modified by adding 1.5 mb to each one.

Further light is given to this issue by examining HJA climate values for extreme SOI years. Two sets of extreme SOI years have been provided respectively by Yarnal and Diaz (1986) and Halpert and Ropelewski (1992). Yarnal and Diaz identified a number of warm (El Nino) and cold (La Nina) event winters (Dec, Jan and Feb). During warm event winters, HJA precipitation is near average at 0.03 SD of the long term (1914-1991) mean and the temperature is well above (0.77 SD) the long term (1890-1991) mean. During cold event winters HJA precipitation is well above (0.69 SD) the long term mean and temperature is below it (-0.33 SD). Halpert and Ropelewski defined warm event years as those in which the SOI index value remained in the lower 25% of the distribution for 5 months or longer and similarly defined cold events years by using the upper 25% of the distribution. By these definitions, at the HJA during warm event years, the annual precipitation is near the long term mean (-0.02 SD), the winter water year precipitation is slightly above the long term mean (0.15 SD) but the following winter water year is markedly below the long term mean (-0.32 SD). Also during warm event years, HJA temperatures are well above the long term mean (0.45 SD). During cold event years HJA annual precipitation is well above the long term mean (0.48 SD) although the winter water year precipitation is near the long term mean (-0.05 SD). Most striking however is that during cold event years the following winter water year is 0.88 SD above the long term mean. Also during the cold event years the annual mean temperature is notably below (-0.37 SD) the long term mean.

Thus it seems there are definite relationships such that during many warm events (El Nino) years the winter water year precipitation at the HJA Forest is relatively low and the annual mean temperatures are relatively high. During cold events (La Nina) the winter water year precipitation at the HJA Forest is relatively high, especially in the winter water year following a calendar year with a cold event, and the annual mean temperatures are relatively low. These findings are consistent with those of Yarnal and Diaz (1986) and Redmond and Koch (1991). The latter noted for the PNW as a whole that precipitation is low and temperature is high during low SOI values with the opposite also being true. Interestingly they found that the relationship tended to be strongest in the mountainous climate divisions. They point out that a combination of low precipitation and high temperature values implies a smaller than average snowpack during El Nino years.

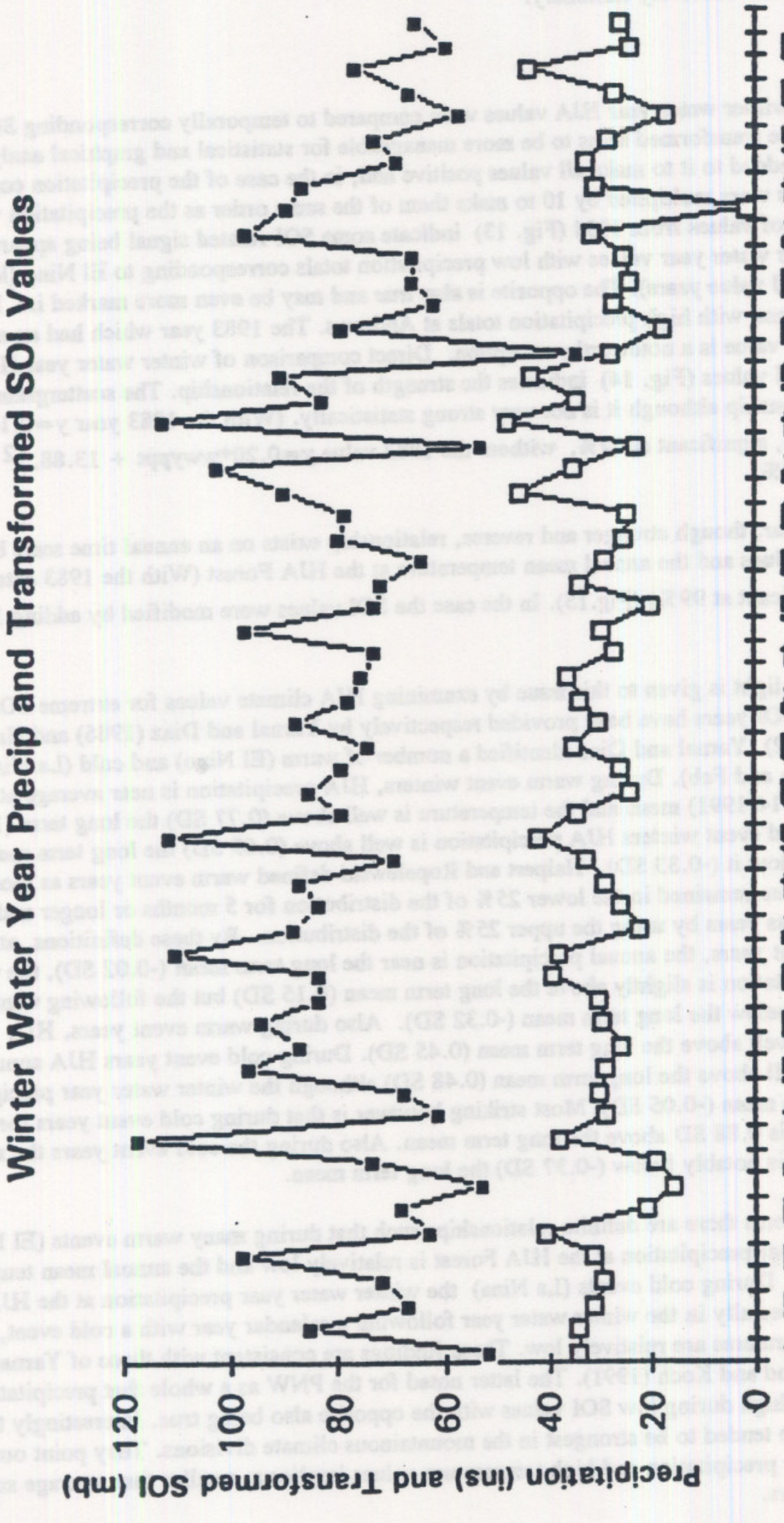


Fig. 13. Annual values of the transformed SOI index and winter water year precipitation at the H. J. Andrews Experimental Forest.

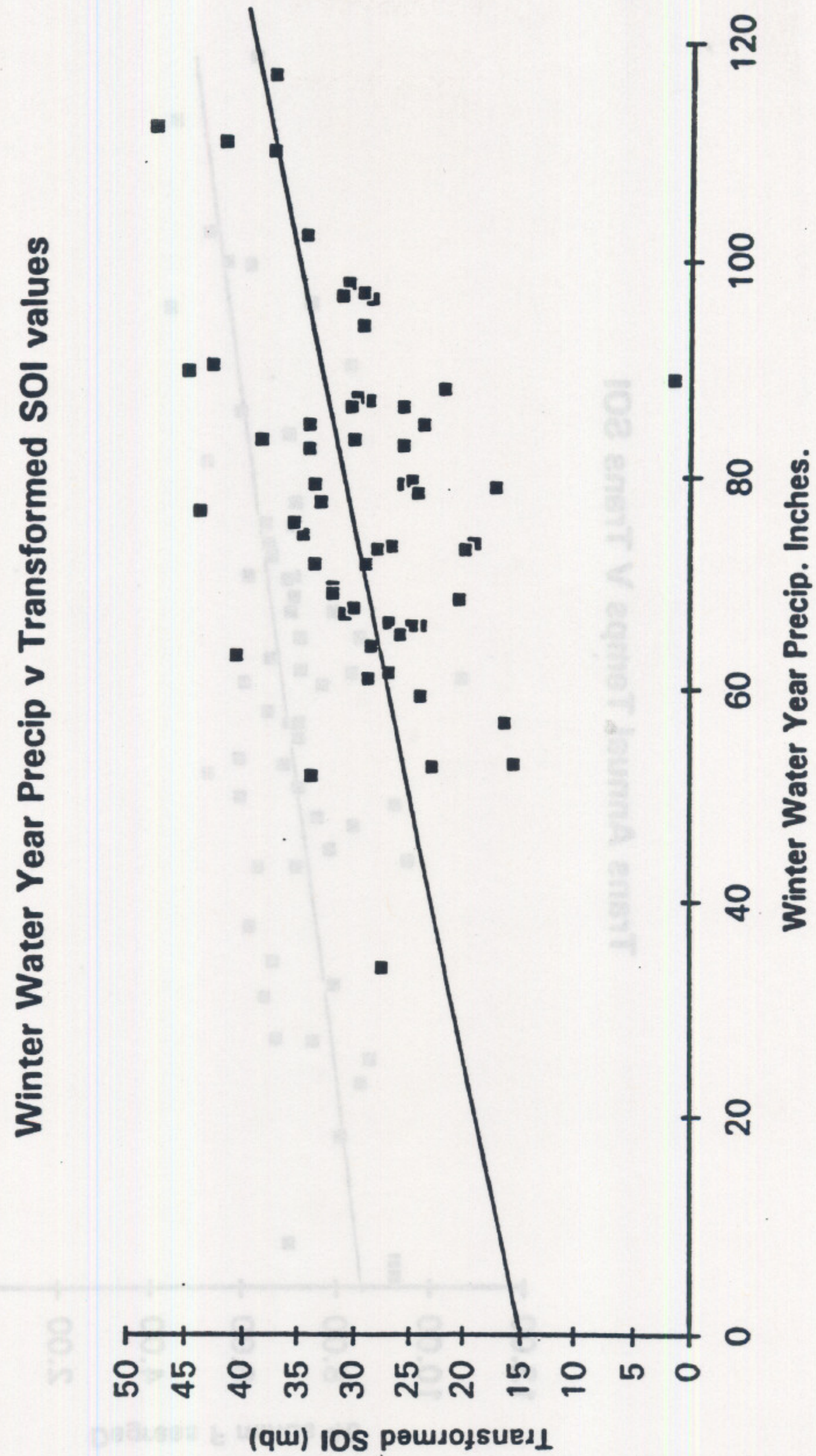


Fig. 14. The relationship between transformed SOI values and winter water year precipitation at the H. J. Andrews Experimental Forest.

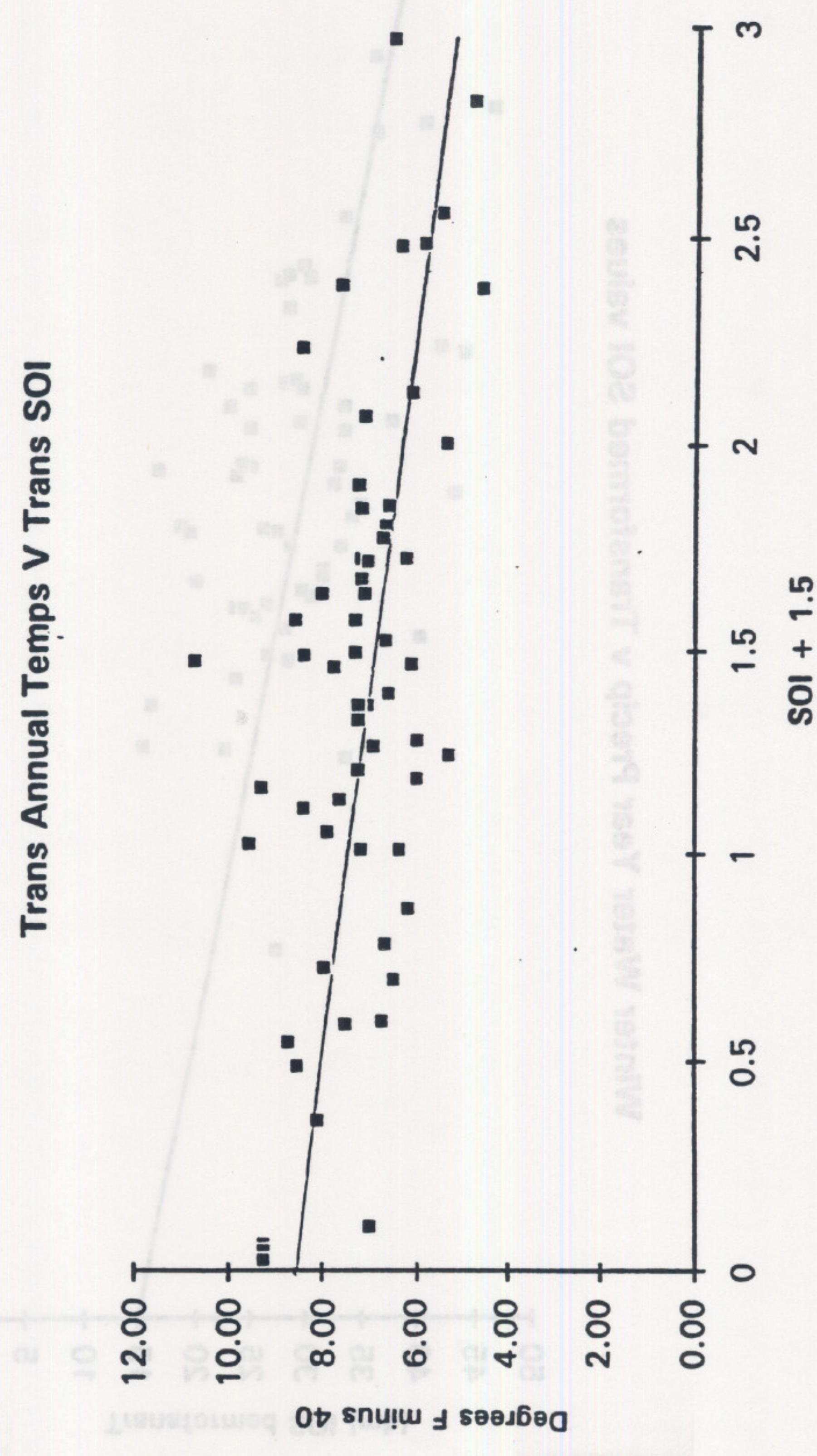


Fig 15. The relationship between transformed SOI values and annual mean temperatures at the H. J. Andrews Experimental Forest.

The relationships found by Redmond and Koch (1991) referred to a lagged relationship in which average SOI values between June and November were correlated with total precipitation between October and March thus implying a lagged "cause and effect" which, if true, could possibly be used for seasonal forecasts. In order to inquire whether there was any time lag in the effect of SOI on HJA data, an analysis was performed in which January values of total precipitation and mean temperatures at the HJA Forest were correlated against lagged values of the SOI index month by month for up to 12 previous months. With one exception, there were no significant correlations in either precipitation or temperature. The exception was a weak relationship between HJA January precipitation and the SOI value of the previous March ($r^2 = 0.10$ significant at 95%). The relationship is interesting enough to pursue at a later time using seasonal as opposed to monthly data.

With respect to making seasonal climate forecasts for the HJA, researchers should be aware that almost real time values of the PNA and SOI indicies and discussions of the forecasted climate are available in the "Climate Diagnostics Bulletin". ENSO (i.e. El Nino event) advisories are published when appropriate in the "Weekly Climatic Bulletin". Both publications are produced by the Climate Analysis Center of the National Weather Service, NOAA, Washington D.C. 20233, and are also available in most university libraries in Government Documents sections.

CONCLUSIONS

Researchers at most LTER sites would benefit by having a climate record at their sites extended back into the last century. The foregoing discussions provide a model methodology for local climate analysis and synthesis at LTER sites. While synthesis by regression analysis is not new, the placement of the site into its regional context by using relations with Climatic Division data and local and hemispheric general circulation indicies does provide a new method of viewing the local climatic environment. This methodology will become increasingly important as LTER sites begin to scale up to landscape and regional levels. It should be noted that it can not be assumed *a priori* that any single LTER site will relate well to the larger regional climatic environment. This has been demonstrated, for example, at the Niwot Ridge, Colorado, LTER site (Greenland and Swift, 1991).

The goal of this study, to analyze the long-term record of the HJA in relation to other research in the Forest, is regarded as being only partially achieved. The analysis has been successful in terms of the major overall trends in the data. It is certainly important for the ecological researchers to know that the warming of approximately the last two decades is, so far, no greater than a similar warming which took place at the beginning of the century, and that the drought of the late 1980s and early 1990s was similar in magnitude to that of the mid 1970s and similar in magnitude but not, so far, duration to that of the 1930s. It is also important to note that the HJA record agrees in general with the tree ring record of the larger scale region. However, the goal will not be fully achieved until HJA researchers begin to work with the extended data record provided in this report and relate it to their own particular area of interest within the ecosystem.

The third goal of placing the climate of the HJA into its regional context has been amply achieved. The general hypothesis was that:

The climate of the HJA Forest is well representative of the climate of the northern Cascades and their foothills in particular and of the PNW in general.

Comparisons of the HJA climate with values from nearby Climatic Divisions, and local and hemispheric general circulation indicies all suggest that the hypothesis is verified. The only exception to this is that as one moves to the larger geographic scale indicies the relationships become less strong and even non-existent in the summer months. The reason for this is that during these months the HJA is usually dominated by a ridge of high pressure and the processes of microclimatology tend to dominate those of larger scales. In contrast, in winter with the expansion of the high energy circumpolar vortex into mid latitudes, and with our growing awareness of the linkages between tropical and extra-tropical circulations, it is not surprising that the HJA is well coupled with these hemispheric scale events. This coupling has important implications for the climate of the HJA one or two, or possibly more, seasons ahead and thus allowing a new dimension in planning ecological experiments.

The most important findings of this study may be summarized as follows:

1) It is feasible to extend backwards in time, records of mean monthly precipitation and mean monthly temperature.

2) The synthetic record shows considerable interannual variability both in precipitation and in temperature.

3) The warming of approximately the last two decades is, so far, no greater than a similar warming which took place at the beginning of the century. The recent warming is found not only in minimum temperatures but also in maximum and mean temperatures. It is found in all seasons but is most marked in spring. For the most part it is paralleled by, but is greater than, the warming at Corvallis and Cottage Grove.

4) The drought of the late 1980s and early 1990s was similar in magnitude to that of the mid 1970s and similar in magnitude but not, so far, duration of that to the 1930s.

5) Both the precipitation and the temperature record at the HJA are in general agreement with what is known from other studies of temporal changes in Oregon and the PNW.

6) The HJA record agrees in general with the tree ring record of the larger scale region.

7) There is evidence that a step function at 1976 which has 'een found in other biophysical time series in the PNW also occurs in HJA precipitation and temperature values. There was no evidence found in these values for a step function centered on 1957.

8) The climate record of the HJA is closely related to that of the Willamette Valley and Northern Cascades climatic divisions of Oregon.

9) Local GCM-related indicies are quite well related to the HJA climate record in winter but not in summer. Hence, we can have some confidence that whatever climatic change is projected by GCMs for the PNW will be applicable in large measure to the HJA Forest in winter and for the winter water year. Since most vegetative growth takes place in the spring and summer months, the ecological implications of this climatic finding should be noted.

10) By the standards usually applied in synoptic climatology there are quite strong relationships between the HJA winter water year precipitation and annual and January mean temperatures and both the PNA and the CNP indicies. No relationships are found for July. The CNP index is a particularly well correlated with January and annual temperatures at the HJA. This is indicative of the importance of the magnitude and position of the Aleutian low pressure cell to the HJA temperatures.

11) There is a weak but definite signal between the SOI (ENSO) index and the climate of the HJA such that during many warm events (El Nino years) the winter water year precipitation at the HJA Forest is relatively low and the annual mean temperatures are relatively high. During cold events (La Nina) the winter water year precipitation at the HJA Forest is relatively high, especially in the winter water year following a calendar year with a cold event, and the annual mean temperatures are relatively low.

It is possible to make the following suggestions for future work on the climate of the HJA:

1) Little attention has been given in this report to intra watershed climatic relations and variability in the HJA. This is, in part, because of the difficulty in obtaining directly comparable data between the various sites in the watershed and with problems of missing data and observing system design. It is suggested that the HJA climate observing system be thoroughly reviewed so as to make it more effective.

2) It would be of interest to examine further the actual values of lapse rates in the PNW and how they vary by season and elevation. This is important because such lapse rate values are often used in the climate driving parts of ecological models.

3) The poor relationships between the local general circulation indicies and HJA climate values in summer should be re-examined and could almost certainly be improved by using 700mb pressure data instead of MSLP data.

4) Since there is a relationship in between the PNA index and the HJA data, particularly in winter, it would be interesting to inquire if the step function of the late 1950s in the PNA index is represented in the winter HJA data.

5) The potential for seasonal forecasting of winter temperatures and precipitation values at the HJA from previous values of the SOI is quite strong and should be investigated. The split sample technique of Redmond and Koch (1991), in which only extreme values of SOI are considered, should be used in such an analysis.

In order to provide an understanding of the climate of any place on the Earth's surface, processes from the two major complementary parts of the discipline of climatology must be addressed. One part is the vertical flows of moisture and energy to and from the Earth's surface. This falls in the field of physical climatology. The second is the horizontal, advective, flow of moisture and energy over the location of interest. This falls in the realm of dynamic and synoptic climatology. The climate of the HJA Forest, when looked at in this perspective, takes on a somewhat different character between the summer, and to a lesser extent fall months, on the one hand, and the winter and spring months on the other. During the winter and spring, when the great circumpolar belt of westerly winds has expanded equatorwards to cover all of the midlatitudes, the climate of the HJA Forest is truly a child of the interaction between ocean and atmosphere over the Pacific ocean. Climatic events and episodes are well coupled to those at the hemispheric scale. During the summer, particularly when the circumpolar vortex is well to the north and the HJA finds itself under the influence of a major ridge of high pressure and stable air, processes of physical climatology dominate. Associated with small solar zenith angles at noon, large amounts of short wave radiation interact with the many different slopes, aspects, and surface cover types of the Andrews. How this energy is absorbed and partitioned among the different flows of the surface energy budget now becomes the dominant feature of the HJA climate. This present study has concentrated on the synoptic and dynamic factors. A future study would do well to focus on the surface energy flows of the summer months when many processes of the ecosystem are at their most intense.

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Appendix 1. Observed and synthetic monthly total precipitation (inches) at the H. J. Andrews Primary Meteorological Site.

Simulated and Observed Monthly Total Precipitation. Inches.														
H.J. Andrews Forest Primary Meteorological Station														
													Water	Winter
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	An Tot	Year	Water Yr
1910	12.57	15.04	4.63	5.97	2.50	3.33	0.30	0.43	1.81	5.59	19.96	8.64	80.78		
1911	20.51	6.77	3.91	6.73	7.48	2.17	0.32	0.44	8.34	3.34	11.43	10.38	81.82	90.86	72.12
1912															
1913	12.95	4.44	9.55	6.39	4.06	5.30	1.04	0.85	4.64	7.45	13.51	6.38	76.55		
1914	20.71	9.81	7.64	8.69	3.62	4.05	0.30	0.42	0.19	10.01	11.40	7.36	84.20	82.76	74.19
1915	12.69	8.43	5.61	4.45	4.80	1.29	1.16	0.42	0.94	3.27	19.01	15.99	78.05	68.56	59.95
1916	12.83	14.17	19.77	5.18	5.36	2.85	2.16	0.45	1.34	2.94	14.39	11.19	92.62	102.36	90.21
1917	8.05	8.83	10.37	8.49	3.49	1.84	0.30	0.43	4.37	0.90	11.82	25.90	84.80	74.69	64.27
1918	14.31	15.29	7.77	4.25	2.91	0.36	0.65	0.92	1.26	5.67	11.59	8.53	73.52	86.36	80.25
1919	17.91	18.83	13.49	8.10	4.30	1.87	0.25	0.17	5.34	6.92	16.82	13.79	107.80	96.05	84.13
1920	6.03	1.63	13.32	10.20	2.08	3.76	0.58	1.70	13.01	10.10	12.93	22.23	97.58	89.85	68.71
1921	14.46	16.16	9.30	7.60	2.90	3.07	0.36	0.48	5.68	5.33	24.86	6.13	96.32	105.26	92.78
1922	10.90	8.53	12.09	7.05	2.87	0.82	0.25	1.37	2.93	7.53	8.72	21.69	84.75	83.13	74.89
1923	24.91	5.12	9.15	5.88	4.34	4.68	1.46	0.47	2.60	7.48	7.86	15.68	89.63	96.55	83.01
1924	9.59	10.16	7.82	2.59	2.09	1.96	0.32	0.50	4.68	11.39	19.84	12.27	83.20	70.72	61.17
1925	17.13	13.42	6.36	7.19	4.69	1.78	0.34	1.08	2.38	0.46	7.64	9.73	72.20	97.87	87.60
1926	9.70	18.76	2.17	2.63	4.79	0.22	0.25	3.67	4.78	8.78	18.97	11.79	86.50	64.78	51.08
1927	13.76	11.29	9.67	5.99	4.20	2.95	0.65	1.18	3.16	7.06	13.75	14.77	88.43	92.39	80.25
1928	11.06	3.43	13.31	7.95	2.27	1.33	0.53	0.00	2.59	5.63	8.55	13.06	69.73	78.06	71.34
1929	16.91	4.80	9.76	8.79	3.84	4.77	0.25	0.05	0.00	3.77	1.54	25.38	79.87	76.42	67.51
1930	8.89	16.18	4.85	6.22	4.75	1.66	0.28	0.01	3.97	5.62	9.46	5.43	67.32	77.49	66.83
1931	7.51	7.76	13.77	4.50	2.29	5.47	0.25	0.02	2.97	7.44	12.48	16.17	80.63	65.06	54.06
1932	14.76	6.74	15.54	6.72	4.91	0.26	0.62	0.62	0.00	8.21	14.95	15.90	89.24	86.27	79.85
1933	18.82	12.12	8.80	2.84	6.20	2.84	0.25	0.59	7.10	4.49	4.06	18.35	86.46	98.62	81.63
1934	13.69	3.54	9.89	3.52	3.35	0.71	0.48	0.15	1.00	10.52	19.81	16.01	82.67	63.23	57.54
1935	11.23	8.24	10.78	6.23	1.52	1.44	0.44	0.56	1.63	7.17	7.10	8.45	64.80	88.42	82.82
1936	21.66	12.59	6.11	2.60	6.25	3.68	0.97	0.00	3.42	0.60	0.19	13.38	72.37	79.98	65.67
1937	13.98	14.50	5.58	13.36	3.59	9.25	0.34	1.45	1.15	9.13	17.85	17.22	117.45	77.37	61.58
1938	12.19	13.45	18.35	5.39	2.28	0.63	0.36	0.07	2.05	5.56	11.69	10.74	83.16	98.96	93.58
1939	10.04	14.57	7.24	1.31	3.14	2.46	0.69	0.57	1.04	7.58	1.25	15.15	62.35	69.07	61.16

Simulated and Observed Monthly Total Precipitation. Inches.														
H.J. Andrews Forest Primary Meteorological Station														
													Water	Winter
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	An Tot	Year	Water Yr
1940	5.80	21.02	9.37	4.41	2.62	1.14	0.60	0.04	4.91	6.95	13.06	9.97	81.00	73.90	64.59
1941	9.70	4.31	2.14	4.34	7.22	3.73	0.51	1.31	6.21	6.78	13.41	17.83	82.95	69.46	50.48
1942	7.94	10.22	3.08	4.21	6.53	3.39	1.28	0.06	0.08	6.28	28.96	29.99	106.72	74.82	63.48
1943	16.60	8.21	11.27	5.96	3.40	5.20	0.39	2.00	0.06	10.42	7.54	5.03	80.18	118.32	107.27
1944	6.29	8.80	6.63	7.56	2.74	1.99	0.56	0.15	2.66	2.57	9.65	4.51	50.97	60.37	52.27
1945	13.08	14.93	11.34	7.98	6.89	0.37	0.39	0.67	3.14	3.45	25.28	18.62	113.56	75.53	64.08
1946	16.62	10.91	10.95	2.97	2.20	2.74	0.64	0.58	2.14	11.83	16.89	13.50	94.69	96.90	88.80
1947	11.12	5.78	11.00	6.15	1.45	7.55	1.81	1.09	1.50	14.55	11.97	9.14	94.79	89.67	76.27
1948	14.98	15.44	9.47	6.23	5.94	2.22	0.63	1.56	3.20	5.06	16.83	21.09	110.90	95.33	81.78
1949	4.97	18.87	5.51	2.54	6.33	0.83	0.20	0.07	2.46	6.30	10.20	9.97	70.72	84.76	74.87
1950	23.27	12.06	10.17	5.03	2.61	3.94	0.35	1.08	2.31	18.43	14.91	13.10	123.82	87.29	77.01
1951	21.87	11.45	12.42	2.20	3.97	0.00	0.21	1.00	1.76	17.50	14.82	16.84	104.49	101.32	94.37
1952	10.68	11.04	9.31	2.03	1.87	4.33	0.19	0.00	1.12	0.62	2.40	17.16	58.94	89.74	82.22
1953	24.76	16.18	10.58	5.15	6.92	3.20	0.20	1.67	0.07	3.96	19.17	19.14	122.42	88.91	76.85
1954	22.25	7.97	7.60	5.21	3.01	4.86	0.48	1.47	2.94	5.95	6.72	13.36	80.26	98.07	85.30
1955	8.09	6.32	14.68	12.15	2.62	1.89	0.88	0.00	3.05	12.62	17.27	30.56	114.28	75.70	67.27
1956	18.68	11.81	13.41	2.85	5.43	3.04	0.40	0.41	0.14	13.31	3.64	14.65	94.19	116.64	107.21
1957	5.88	12.55	17.76	4.09	5.52	2.04	0.59	0.83	1.57	6.40	7.17	27.25	92.06	82.42	71.87
1958	15.75	15.88	5.13	7.96	2.94	6.54	0.32	0.32	2.27	3.31	19.15	10.76	90.04	97.94	85.55
1959	19.91	9.59	9.88	2.66	4.61	2.44	0.58	0.08	7.84	9.16	6.28	5.58	72.81	90.82	75.26
1960	8.15	12.68	16.66	7.79	9.10	0.19	0.51	1.89	0.83	8.37	21.75	7.54	104.15	78.82	66.30
1961	7.34	16.99	15.89	4.60	4.82	0.77	0.30	0.15	3.37	10.57	17.76	15.72	108.73	91.89	82.48
1962	5.96	6.41	15.18	6.77	5.07	0.96	0.20	1.96	3.14	7.77	15.40	5.97	74.65	89.69	78.37
1963	4.59	15.03	6.61	8.84	6.46	4.11	1.35	0.00	5.19	4.37	18.24	7.66	88.91	81.31	64.21
1964	22.83	4.16	10.39	4.05	2.79	2.98	0.52	1.28	1.53	2.93	18.17	35.13	108.22	80.79	71.69
1965	23.14	6.20	2.45	3.93	3.36	0.64	0.41	1.62	0.00	3.29	14.16	11.19	68.47	97.98	91.95
1966	20.67	6.96	11.99	1.97	1.68	1.46	1.13	0.13	1.54	7.57	15.94	13.25	84.13	76.19	70.23
1967	18.29	6.72	9.26	5.43	2.66	1.08	0.19	0.00	3.14	12.15	7.01	11.05	69.85	83.54	76.46
1968	10.48	11.40	5.52	3.10	5.00	1.77	0.65	4.14	3.32	9.43	16.40	20.25	101.58	75.59	60.70
1969	16.21	5.87	6.01	4.67	4.01	5.93	0.27	0.01	2.57	7.27	4.85	17.21	79.27	91.62	78.84

Simulated and Observed Monthly Total Precipitation. Inches. H.J. Andrews Forest Primary Meteorological Station														Water	Winter
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	An Tot	Year	Water Yr
1970	20.96	7.15	6.34	7.36	2.83	1.63	0.21	0.00	4.83	8.01	16.48	15.17	92.29	80.66	71.16
1971	21.10	11.08	12.54	6.61	4.11	4.02	0.40	0.85	6.40	7.22	17.82	17.45	108.91	106.78	91.00
1972	21.55	12.90	14.44	8.58	4.22	1.91	0.21	0.88	5.10	1.75	7.70	15.54	99.80	112.30	99.97
1973	11.05	4.12	6.75	3.98	2.32	3.43	0.01	0.79	6.83	7.30	27.36	21.64	95.56	64.27	50.89
1974	18.00	14.63	16.49	6.90	3.53	2.63	0.62	0.21	0.14	1.89	10.15	19.53	94.72	119.45	112.32
1975	18.47	14.31	14.09	4.20	3.50	1.44	1.06	3.02	0.00	12.08	15.80	15.41	103.39	91.66	82.64
1976	19.22	13.14	9.69	5.26	2.37	1.12	0.89	3.55	0.81	4.39	2.76	2.89	66.09	99.34	90.60
1977	3.19	7.00	11.20	2.33	7.46	0.93	0.23	3.59	5.49	6.11	20.04	25.40	92.95	51.46	33.76
1978	9.56	7.45	3.27	7.31	4.61	2.07	0.85	3.80	4.44	0.96	10.09	11.00	65.41	94.91	79.14
1979	5.35	18.56	7.76	7.94	4.41	0.84	0.70	1.33	2.51	10.36	9.76	9.22	78.74	71.45	61.66
1980	13.17	8.30	9.70	5.57	3.03	3.48	0.41	0.39	1.84	3.29	13.76	19.95	82.89	75.23	66.08
1981	3.61	12.41	7.68	5.30	4.28	6.30	0.87	0.05	5.08	7.78	12.66	29.51	95.53	82.58	66.00
1982	16.21	14.52	7.04	9.07	0.79	3.61	0.75	1.59	4.27	11.48	10.08	17.43	96.84	107.80	96.79
1983	14.69	16.19	14.70	4.38	4.96	3.60	2.48	2.38	0.74	3.35	20.11	17.27	104.85	103.11	88.95
1984	7.42	15.11	14.18	9.09	7.94	7.35	0.15	0.17	2.72	13.41	23.06	10.05	110.65	104.86	86.53
1985	0.56	8.56	9.30	4.04	2.30	3.28	0.29	0.80	4.81	9.44	11.02	5.72	60.12	80.46	68.98
1986	12.30	21.21	6.74	6.90	4.84	0.47	1.51	0.00	11.13	4.38	18.36	4.84	92.68	91.28	73.33
1987	12.04	7.01	7.30	2.87	3.89	0.49	2.73	0.04	0.42	0.06	7.54	15.51	59.90	64.37	56.80
1988	13.98	8.17	12.22	8.86	6.46	3.21	0.14	0.00	2.62	0.59	27.44	9.37	93.06	78.77	66.34
1989	13.89	5.90	15.26	4.54	4.62	1.22	0.98	3.87	0.64	3.55	8.65	3.67	66.79	88.32	76.99
1990	18.70	11.43	4.25	9.08	4.62	3.39	0.62	2.38	0.54	9.23	13.23	7.23	84.70	70.88	59.33
1991	9.13	8.18	8.70	9.50	7.66	2.05	1.30	0.84	0.01	6.52	17.77	8.41	80.07	77.06	65.20

SIMPPT.XLS

Andrews	Ppt	Inches	1914	-1991									
Yr	J	F	M	A	M	J	J	A	S	O	N	D	An Tot	WWY
Long Mn	13.51	10.92	9.87	5.77	4.12	2.64	0.62	0.94	2.88	6.87	13.40	14.46	87.56	74.72
Long SD	5.82	4.51	3.98	2.48	1.72	1.90	0.52	1.07	2.47	3.91	6.37	6.83	16.06	14.41
+1 SD	19.33	15.42	13.85	8.25	5.84	4.54	1.14	2.01	5.35	10.78	19.77	21.29	103.62	89.14
-1SD	7.69	6.41	5.89	3.29	2.40	0.74	0.11	-0.13	0.42	2.96	7.03	7.62	71.49	60.31

Long-term (1914-1991) mean, standard deviation (SD) and value of monthly total precipitation plus one standard deviation (+1 SD) and minus one standard deviation (-1 SD). Values are in inches.

Appendix 2. Observed and synthetic monthly mean temperature (°F) at the H. J. Andrews Primary Meteorological Site.

Simulated and observed mean monthly temperatures. Deg F.
H.J. Andrews Forest Primary Meteorological Station

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1890	27.35	29.79	37.94	46.25	56.54	58.05	61.12	61.49	54.62	45.02	37.16	35.69	45.92
1891	33.25	28.87	35.56	44.72	53.53	55.59	63.05	64.42	52.58	48.05	41.48	34.76	46.32
1892	32.80	34.94	40.79	40.75	52.37	57.12	60.78	63.02	55.55	47.29	39.00	34.42	46.57
1893	27.08	32.08	37.82	39.34	49.94	54.73	60.70	60.32	50.82	42.82	37.16	35.62	44.04
1894	34.50	30.93	36.98	44.08	51.33	56.10	62.80	64.31	53.23	45.32	39.43	33.15	46.01
1895	32.62	35.17	37.34	45.61	50.98	58.22	63.72	61.26	49.99	46.61	35.22	34.02	45.90
1896	35.75	38.84	37.82	40.75	47.73	57.29	65.32	62.31	53.32	46.76	31.76	36.22	46.16
1897	32.80	36.43	33.89	49.83	58.17	58.48	61.29	65.95	52.95	46.76	39.32	36.16	47.67
1898	33.42	39.75	37.34	47.66	52.02	58.65	62.63	63.72	55.64	45.17	36.94	32.35	47.11
1899	36.37	30.70	36.75	43.05	49.36	56.61	62.88	57.39	56.29	45.55	44.94	35.09	46.25
1900	36.02	35.51	45.79	47.40	52.60	59.33	62.72	57.39	52.95	46.68	41.91	36.76	47.92
1901	32.89	35.97	39.72	45.36	53.53	55.67	60.61	64.42	52.03	50.32	41.27	34.09	47.16
1902	31.91	39.75	38.41	43.57	52.37	58.48	61.87	62.78	54.25	47.44	37.81	34.09	46.89
1903	34.59	31.39	37.82	42.67	52.49	59.24	60.53	60.44	54.53	46.61	38.67	33.95	46.08
1904	34.50	34.25	35.91	49.58	53.53	59.07	63.14	63.25	55.73	47.82	42.13	35.29	47.85
1905	34.23	35.86	44.24	49.58	51.79	58.05	65.83	61.73	55.46	45.17	35.76	33.82	47.63
1906	37.09	37.92	37.94	50.35	52.25	56.10	67.42	64.19	55.18	47.59	39.32	36.16	48.46
1907	29.94	41.13	38.17	47.92	54.69	58.90	63.39	61.02	55.08	49.33	40.51	36.29	48.03
1908	35.66	35.86	39.24	47.02	47.62	56.69	66.84	61.14	53.51	46.38	41.48	33.02	47.04
1909	29.13	36.77	40.55	44.84	48.78	58.39	60.45	59.26	55.55	47.36	38.24	34.42	46.15
1910	33.25	30.82	41.86	46.25	55.15	56.44	63.64	59.03	53.32	47.29	38.03	34.49	46.63
1911	29.49	31.05	40.79	41.01	47.50	54.99	66.58	64.42	48.69	45.62	38.03	33.75	45.16
1912	35.93	40.10	36.98	43.57	54.11	58.90	63.14	56.68	55.18	44.11	39.00	34.89	46.88
1913	32.71	31.96	38.29	45.10	51.67	57.97	62.88	63.13	53.69	46.83	40.29	34.49	46.59
1914	38.43	36.09	44.00	48.81	55.27	56.18	64.73	61.73	53.23	48.88	39.00	31.02	48.11
1915	32.89	37.69	45.19	51.37	51.91	62.22	63.39	65.01	53.97	46.76	39.00	36.96	48.86
1916	27.17	40.44	39.96	46.64	48.43	57.46	60.95	64.89	53.97	43.81	35.65	33.09	46.04
1917	31.75	33.52	33.40	42.85	51.24	57.41	65.10	65.45	55.73	49.16	41.73	38.47	47.15

Simulated and observed mean monthly temperatures. Deg F.													
H.J. Andrews Forest Primary Meteorological Station													
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1918	38.22	34.92	39.65	45.58	50.53	62.58	62.97	62.68	60.35	48.99	37.83	33.16	48.12
1919	32.73	34.40	38.93	45.87	51.22	57.64	64.21	63.32	54.76	45.12	38.30	29.79	46.36
1920	33.37	32.94	37.25	41.48	48.21	57.22	63.06	64.23	53.26	45.15	36.98	34.86	45.67
1921	33.34	38.68	40.40	44.00	51.19	59.32	61.97	61.65	52.41	48.60	41.25	32.23	47.09
1922	29.29	31.30	35.53	40.70	52.92	60.45	64.43	61.13	55.94	47.59	33.87	33.28	45.54
1923	34.40	30.75	37.25	45.79	52.34	57.79	63.45	65.56	56.29	47.91	41.50	33.96	47.25
1924	32.15	40.63	37.64	46.65	56.34	59.48	62.61	62.67	54.48	46.72	36.91	27.96	47.02
1925	36.96	39.66	39.92	47.99	56.08	59.10	63.96	60.50	54.54	46.23	38.65	35.96	48.30
1926	34.26	39.95	45.28	54.51	53.36	61.44	64.68	62.84	53.40	49.08	42.26	34.78	49.65
1927	33.76	36.19	37.97	43.69	49.87	59.09	64.01	63.27	54.70	48.17	42.90	32.13	47.15
1928	35.08	36.78	44.22	44.98	57.38	59.03	65.09	63.27	55.54	47.50	39.96	32.64	48.46
1929	29.23	28.68	41.28	41.68	53.27	58.78	63.80	64.67	57.27	50.31	36.88	36.45	46.86
1930	24.13	40.10	44.01	51.81	51.22	58.63	63.29	65.53	56.44	47.16	37.83	33.49	47.80
1931	36.81	36.69	42.72	51.24	59.39	59.53	66.08	64.47	55.76	48.68	37.10	33.07	49.29
1932	33.52	34.64	42.42	46.52	52.89	61.72	61.90	64.29	57.66	50.00	42.60	30.90	48.25
1933	32.75	31.71	40.19	46.28	48.34	58.53	64.03	65.55	53.02	48.14	38.94	38.37	47.16
1934	39.27	41.45	48.85	53.01	56.50	59.17	63.19	64.42	55.07	49.77	42.74	35.25	50.72
1935	32.12	36.90	35.35	45.19	52.19	60.48	63.80	64.89	59.94	46.91	35.26	33.09	47.18
1936	37.01	27.10	39.32	49.96	56.98	58.93	63.48	64.19	56.51	48.89	36.82	34.69	47.82
1937	23.09	31.63	43.00	43.37	54.76	59.09	64.68	62.16	57.01	49.99	42.22	36.46	47.29
1938	35.52	36.59	39.59	47.48	55.15	59.55	67.81	60.23	58.81	47.08	35.95	34.32	48.17
1939	35.51	33.35	42.00	50.49	55.19	54.95	65.61	64.50	58.06	47.38	42.69	38.42	49.01
1940	37.06	39.27	45.53	49.06	57.83	57.47	65.18	65.39	57.49	49.33	38.54	35.81	49.83
1941	37.21	43.79	47.34	48.49	54.17	56.52	67.59	63.84	54.46	46.55	42.74	35.63	49.86
1942	32.90	35.57	40.92	47.44	52.37	55.09	66.44	66.56	57.13	47.24	39.98	33.33	47.92
1943	29.65	39.95	40.34	49.64	51.96	55.09	64.15	61.60	59.43	47.48	41.09	33.34	47.81
1944	34.27	35.71	40.95	45.37	53.43	57.16	65.10	61.71	59.17	49.92	37.86	33.33	47.83
1945	35.74	36.76	38.38	43.79	54.52	56.92	65.51	65.15	55.50	46.56	39.89	35.13	47.82
1946	33.62	36.62	40.22	45.88	55.59	53.55	63.65	63.57	54.88	44.08	37.98	34.88	47.04
1947	29.31	41.67	44.37	49.04	57.51	55.72	63.18	60.50	57.65	48.13	40.74	35.47	48.61
1948	31.98	35.30	38.44	42.36	52.29	57.51	62.81	60.71	55.52	45.84	36.58	30.39	45.81

Simulated and observed mean monthly temperatures. Deg F.
H.J. Andrews Forest Primary Meteorological Station

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1949	23.76	32.29	40.52	48.70	56.11	57.34	63.00	62.42	56.70	42.59	42.83	33.15	46.62
1950	26.33	30.20	38.86	44.59	53.16	56.32	65.16	66.60	57.21	48.08	41.09	38.08	47.14
1951	32.29	35.91	34.66	48.83	53.53	58.94	64.56	61.92	57.59	45.46	40.23	33.08	47.25
1952	30.77	35.30	38.16	48.52	54.22	56.56	64.84	65.73	58.80	49.92	31.95	35.03	47.48
1953	41.17	38.49	38.71	44.81	50.40	57.92	63.05	63.89	58.23	48.15	42.43	36.19	48.62
1954	32.75	40.73	36.90	45.94	53.73	53.29	61.48	58.50	54.94	45.41	43.79	34.88	46.86
1955	32.01	32.80	35.35	38.93	49.60	57.69	60.65	61.92	54.98	46.32	35.90	35.72	45.16
1956	33.79	28.89	37.76	46.95	54.61	55.67	64.97	62.88	56.58	45.39	35.02	34.63	46.43
1957	26.78	35.57	40.58	47.57	54.63	58.02	61.72	59.65	59.14	46.44	36.29	36.42	46.90
1958	37.67	42.89	38.87	45.37	58.15	59.93	67.70	68.32	56.45	47.99	40.13	38.84	50.19
1959	35.20	37.09	40.15	48.05	50.49	59.31	65.22	62.42	53.89	46.72	37.74	35.36	47.64
1960	32.57	36.04	39.31	46.03	49.97	60.15	65.65	61.23	56.63	46.75	37.58	35.01	47.24
1961	39.08	39.75	39.67	45.85	51.98	62.66	64.86	68.11	53.55	45.34	34.48	34.55	48.32
1962	34.14	34.15	36.96	49.46	48.88	57.48	62.96	63.20	57.06	45.91	40.57	36.16	47.24
1963	35.58	44.57	39.50	42.38	53.50	56.92	60.53	64.09	59.73	47.20	39.31	36.00	48.28
1964	33.84	34.62	37.96	42.76	49.16	56.49	63.10	61.46	54.14	47.52	35.42	34.39	45.91
1965	33.39	37.97	42.19	47.74	49.93	58.13	64.81	64.65	54.82	49.13	42.12	32.86	48.14
1966	33.36	34.90	39.44	47.79	53.41	58.71	62.88	62.75	57.54	46.53	40.73	35.86	47.83
1967	34.36	35.85	37.35	41.07	52.25	60.40	65.17	69.11	59.24	47.11	40.00	31.81	47.81
1968	33.08	42.04	42.50	43.11	51.32	58.63	64.62	62.44	55.77	46.31	39.76	32.15	47.65
1969	27.31	30.77	40.95	44.97	55.66	59.06	62.00	60.54	56.18	45.69	38.52	39.17	46.74
1970	35.06	39.87	40.15	40.32	52.32	61.46	64.48	63.65	53.24	45.51	39.62	32.55	47.35
1971	31.29	35.52	35.64	42.66	52.01	55.87	63.94	67.24	54.00	44.62	37.13	32.05	46.00
1972	31.08	37.33	42.56	41.69	53.86	58.55	66.03	66.42	54.17	46.65	40.44	29.35	47.34
1973	29.30	36.50	36.70	43.50	54.30	56.70	64.60	61.70	56.30	45.10	33.80	34.50	46.08
1974	29.70	32.40	36.70	42.80	49.10	60.10	62.40	65.30	58.80	46.00	38.30	34.70	46.36
1975	32.90	33.10	34.90	37.80	48.90	55.60	64.40	58.10	55.90	44.60	37.80	33.10	44.76
1976	32.50	33.80	36.70	44.40	52.50	56.70	65.30	62.10	59.90	48.20	42.60	33.10	47.32
1977	31.10	39.20	37.90	48.40	48.40	63.30	64.00	68.50	54.70	47.10	37.80	36.90	48.11
1978	37.00	38.10	44.20	42.60	48.70	58.60	63.50	61.00	52.30	46.90	31.80	27.10	45.98
1979	27.00	32.90	42.40	46.00	54.50	59.50	63.90	60.10	55.90	48.00	34.30	34.70	46.60

Simulated and observed mean monthly temperatures. Deg F.													
H.J. Andrews Forest Primary Meteorological Station													
	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
1980	33.10	40.30	39.90	47.30	51.60	55.00	64.20	59.90	56.30	47.80	41.90	37.40	47.89
1981	38.50	39.00	42.10	47.30	52.00	57.40	62.60	66.60	57.70	44.10	38.50	37.20	48.58
1982	32.40	35.10	39.70	42.60	52.20	59.70	63.00	63.30	55.60	47.70	37.00	35.40	46.98
1983	38.30	40.30	43.30	45.50	54.90	57.00	60.80	64.00	55.00	49.50	41.70	32.50	48.57
1984	34.30	38.10	43.50	43.30	50.90	56.50	65.10	63.70	55.00	45.90	38.70	32.00	47.25
1985	31.50	33.40	37.20	48.20	52.30	60.10	67.10	61.70	52.50	46.40	33.60	29.50	46.13
1986	38.70	39.60	45.50	45.10	53.80	62.10	61.00	66.70	53.40	48.60	41.70	35.40	49.30
1987	33.30	39.00	42.60	50.50	55.40	61.90	61.30	63.50	57.70	49.80	41.40	34.90	49.28
1988	33.30	38.30	40.80	47.30	51.60	57.60	64.20	63.30	57.00	53.10	40.80	34.50	48.48
1989	33.60	29.10	39.90	50.00	52.20	60.10	61.30	61.50	56.30	46.60	40.80	34.00	47.12
1990	37.20	32.50	41.40	50.40	51.30	58.80	66.40	64.80	60.60	46.60	41.40	29.50	48.41
1991	32.00	42.40	40.10	44.40	50.00	56.10	65.50	64.80	59.90	48.00	43.70	37.80	48.73

SIMTEMP.XLS

Andrews	Temp	1890	-1991									
Yr	J	F	M	A	M	J	J	A	S	O	N	D	Year
Long Mn	33.14	35.98	39.80	45.85	52.64	58.12	63.76	63.09	55.60	47.10	38.98	34.34	47.37
Long SD	3.45	3.77	3.03	3.24	2.63	2.00	1.79	2.45	2.28	1.75	2.80	2.25	1.19
+1 SD	36.59	39.75	42.84	49.09	55.27	60.12	65.54	65.54	57.88	48.85	41.78	36.59	48.56
-1SD	29.69	32.21	36.77	42.61	50.01	56.12	61.97	60.64	53.31	45.34	36.17	32.09	46.17

Long-term (1914-1991) mean, standard deviation (SD) and value of monthly mean temperature (°F) plus one standard deviation (+1 SD) and minus one standard deviation (-1 SD).