DROUGHT ANALYSIS AND IMPLICATIONS FOR SALT SPRING ISLAND, BRITISH COLUMBIA

by

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The Bottom Line

The long-term adjusted precipitation time-series for Saanichton was combined with the observed precipitation data from St. Mary Lake (SML) to construct a monthly 100-yr proxy record for Salt Spring Island. This time-series was created by simply blending the two records with the SML data used directly for 1976-2015. Analysis of this blended record, for spring, fall-winter and annual totals, leads to the following conclusions:

1. The 2015 spring drought (April through June) was by far the most severe in the 100-yr record, with a return period well in excess of 100 years.
2. Droughty springs occur throughout the record, but show *no* indication of becoming more frequent or more severe, on average.
3. The likelihood that a droughty spring will be following by a droughty fall and winter, leading to a shortfall in the lake refilling (for St. Mary Lake), is low, of the order of one in 1000 years.
4. There is no doubt that the SML climate is becoming wetter. The data suggest an increase of about 200 mm in the past century, or about 20% of the current annual total of 965 mm.
5. The data also indicate that the year-to-year *variations* in total and fall-winter rainfall (the change from one year to the next) are increasing compared with 100 years ago.

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[1] This report was prepared by the author to document curiosity-driven research. The views expressed herein are those of the author and not of any other person or agency.

1.0 INTRODUCTION

Drought years present challenges for managing water withdrawals from Salt Spring Island lakes, operationally during such years, and for determining a sustainable amount of water that can safely be produced during the critical dry months of July to October over the long-term. 2015 proved especially difficult because precipitation after March was particularly low, leading to the lowest seasonal spring-summer St. Mary Lake levels since the Duck Creek weir was completed in 2006. Knowing the degree of severity of these conditions, and the likelihood of occurrence are of great interest.

Daily precipitation data have been collected at the NSSWD's St. Mary Lake treatment facility since 1976, providing a high quality record for analysis (n = 39 years). Environment Canada has produced long-term (c. 100 yr) data sets for several stations near St. Mary Lake, the most representative being at Saanichton, BC. This record spans 100 years (1914 – 2013).

These records are examined in this paper. Two aspects are explored: (i) the nature and frequency of droughty years, particularly those characterized by early, dry spring seasons, and (ii) long-term climate variations evident in the Saanichton record and what these might mean for Salt Spring Island. The first is of interest because the demand for treated water increases rapidly early in the year, with attendant draw down of the lake before reaching the July-August period of peak demand. The second aspect has a direct bearing on estimating the sustainable water yield.

Watershed area	645 ha
Lake surface area:	182 ha
Lake volume	16,600 dam^3

Figure 1.1 St. Mary Lake, looking south from Dodds Road (painting by the author).

2.0 THE DATA SETS

2.1 NSSWD Record

Daily rainfall data were recorded at the St. Mary Lake water treatment facility, located on the west side of the lake (Fig. 2.1). The site is about 42 m above mean sea level. The land rises sharply to the west of the observing site, forming a high cliff. To the east, the site is open and exposed to the lake. It is less well exposed in both directions along the lakeshore, being sheltered by trees. The topography is unlikely to affect rainfall records, but would not be suitable for wind velocity measurements due to blocking from the west and south. Rain was collected in a tipping bucket rain gauge. Snowfall was measured when present and converted to rainfall using the relation 1 cm of snow = 10 mm of rain. These data were combined to provide an estimate of total daily precipitation, which was analyzed here.

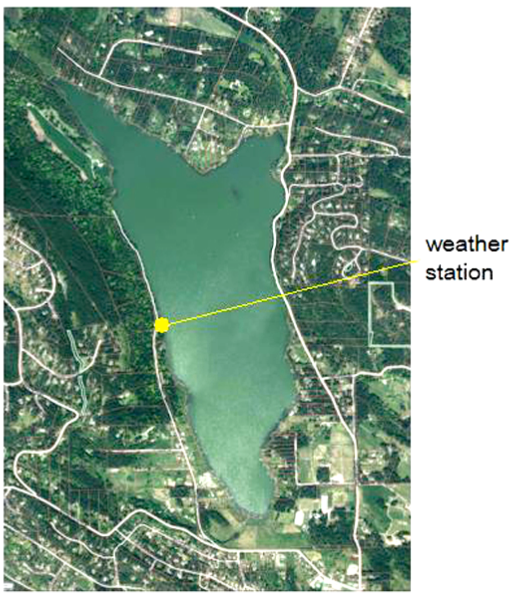


Figure 2.1 St. Mary Lake showing location of the weather observing site (48°53'17" N, 123°32'47" W).

All recordings were logged by hand, entered into a computer file and provided to Environment Canada who archived the data.

2.2 The Adjusted Long-term Record

Environment Canada has created long-term data sets of climate variables, including precipitation, for a number of stations across Canada. These are referred to as the adjusted, homogenized data sets.[1] There are five stations that could be suitable for comparison with St. Mary Lake and I have quickly screened these against the SML record. Saanichton emerged as the closest (see later discussion).

Saanichton is located on the eastern side of Vancouver Island[2] (Saanich Peninsula) and shares the same general climate as Salt Spring Island. It is also at a similar elevation (61 m). The record spans the period 1914 to 2013, although the January and February data of 1914 are missing. In some cases, Environment Canada combined data from different stations to create as long a record as possible; however, this was not done at Saanichton where the data are all from the one site. Presumably this provides a higher quality record than one merged from different sites.

Adjustment of the raw data follows the steps described in Mekis and Vincent (2011)[2]. Daily rainfall gauge and snowfall ruler data were extracted from the National Climate Data Archive. For each rain gauge type, corrections to account for wind undercatch, evaporation, and gauge specific wetting losses were implemented. For snowfall, density corrections based upon coincident ruler and Nipher measurements were applied to all snow ruler measurements. Trace precipitation were adjusted to avoid the underestimation of total precipitation. This has particular importance

[2] Location: 48.62167° N, 123.41889° W EC stn id 1016940

over the Canadian Arctic but is, perhaps, not so critical in our region. Monthly rain, snow and total precipitation were calculated by adding the station's daily rain gauge, snow ruler and total precipitation observations, over the month. The impact of the adjustments on rainfall and snowfall total amounts and trends was examined in detail in Mekis and Vincent (2011).

The long-term monthly record contains six data gaps (out of a total of 1152 values). For analysis purposes, I have filled these gaps with an average of the preceding and following months within the same year. Given the low number of missing values, this procedure should not introduce significant bias into the results and conclusions.

2.3 The Blended Time-series

The approach taken here is to blend the 39-yr record from SML with the 100-yr series from Saanichton, providing a kind of proxy SML record spanning 102 years. This method incorporates decadal and longer period fluctuations, as well as seasonal variations, that cannot be modelled using extreme value analysis of the SML record alone.

The observed time-series are specified as a set of discrete monthly values $\{p\}$ defined on a uniform interval of time Δt, where $\Delta t = 1$ month. Three new series were then calculated from the observed data:

$$\{P_S\} = \Sigma\, p_i,\ i = 4,\ldots,6 \qquad (1)$$

where $\{P_S\}$ = total spring precipitation occurring in April, May and June,

p_i = observed monthly total precipitation in month i,

i = month index, 1 is January, 2 is February, … , 12 is December;

$$\{P_W\} = \Sigma\, p_i,\ i = 9,\ldots,12, \text{ and } i = 1, \ldots, 2 \text{ of the following year} \qquad (2)$$

where $\{P_W\}$ = total fall-winter precipitation occurring from September to February (2015 is not included in the series at the time of writing - October 2015), and

$$\{P_A\} = \Sigma\, p_i,\ i = 8,\ldots,12, \text{ and } i = 1, \ldots, 7 \text{ of the following year} \qquad (3)$$

where $\{P_A\}$ = the annual total precipitation, defined for the hydrological year Aug 1 to Jul 31.

Note: the year for $\{P_A\}$ *contains* $\{P_S\}$. The year for $\{P_W\}$ *follows* $\{P_S\}$. Each series $\{P\}$ constitutes a discrete set defined in a uniform interval of time $\Delta t = 1$ year. Figure 2.1 shows the time-series $\{P\}$ for all three data sets[3]. Visual inspection shows that the SML series are correlated with the Saanichton records; obviously there are five years when it was dryer at Saanichton (mid 80s) in terms of the annual total, but otherwise the series appear to reflect the same general climate.

The Saanichton series are non-stationary in the mean. Thus, in order to derive the precipitation anomaly these series must be de-trended. This has been carried out using a moving average filter (ma) with a time

[3] Plotting convention: generally, I prefer to show the time-series as bar graphs to emphasize that they are discrete values. Plotting the series as connected dots, either with straight lines or smoothed curves, suggests that intermediate data vary smoothly between the defined values, which is not the case. However, some series properties are easier to see when plotted with the latter convention, and I have used it occasionally for clarity (e.g., Fig. 2.1).

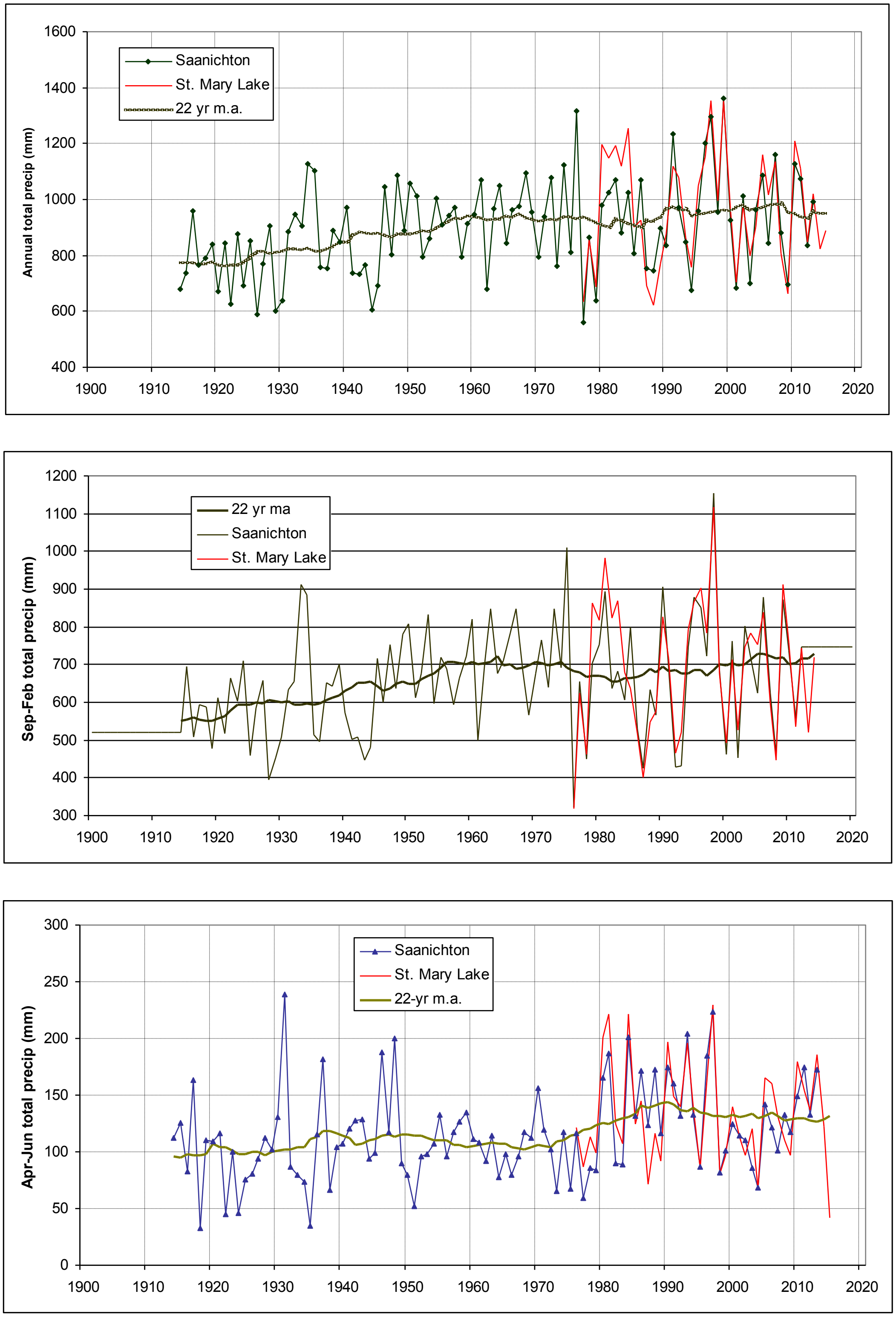


Figure 2.1 Observed time-series for $\{P_A\}$ (upper panel), $\{P_W\}$ (middle panel) and $\{P_S\}$ (lower panel). The 22-yr ma signal is also shown for the Saanichton series.

span of 22 years. The choice of the filter width (22 yr) is based on a visual assessment of the data, and the fact that changes in sunspot activity cycle with approximately an 11-yr period. The ma was applied to the Saanichton series by extending it in both directions by 11 years using a mirror reflection of the first and last 11 values in the observed series. The ma signal $\{P_{ma}\}$ is also plotted in Fig. 2.1.

The precipitation anomaly series were calculated as:

$$\{S\} = \{P\} - \{P_{ma}\} \qquad (4)$$

for both the Saanichton and SML records. A negative anomaly means dryer than the trend.

Blended Spring Anomaly

The spring anomaly $\{S_S\}$ is shown in Fig. 2.2 for the two stations; both are stationary in the mean and variance (no difference at the 1% level of significance). The signals are positively correlated in the period of overlap (Fig. 2.3), with a correlation coefficient of r = 0.84. Since n = 38, the number of degrees of freedom is 36 and at the 1% level of significance r > 0.41, which is satisfied. Thus, there is a theoretical basis for blending the two time-series, and since the variance is equivalent for both stations, this was done without adjusting the variance of either series.

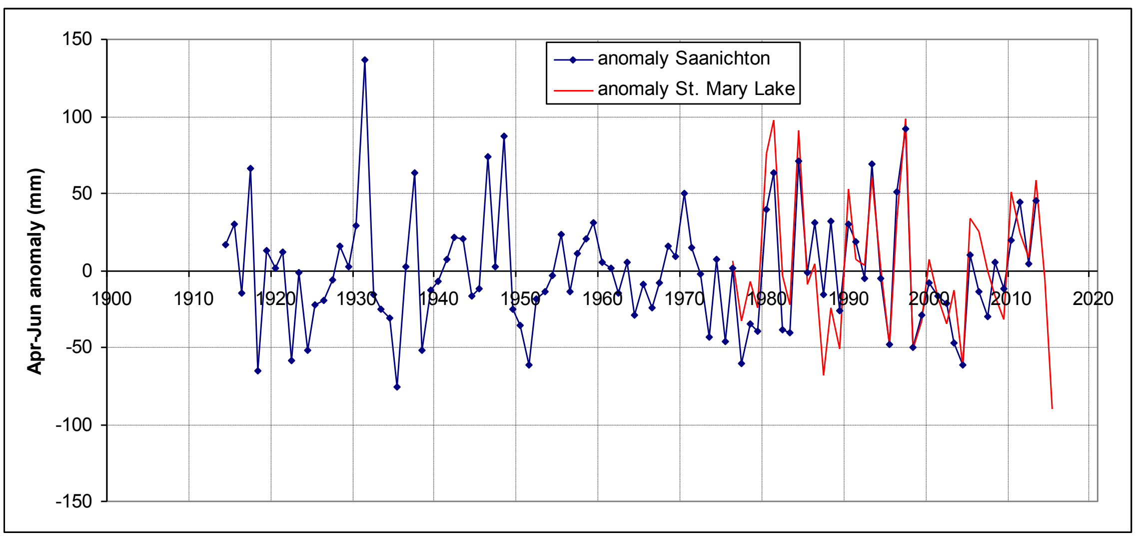


Figure 2.2 Spring precipitation anomaly $\{S_S\}$ for both stations.

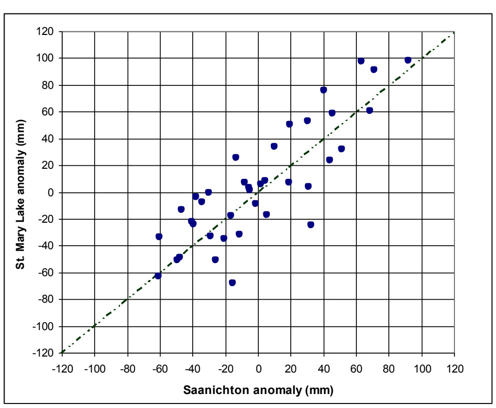


Figure 2.3 Comparison of spring precipitation anomaly for Saanichton with St. Mary Lake. The correlation coefficient r = 0.84.

Before 1976, the Saanichton anomaly values were used as calculated from (4), and from 1976 to 2015 the SML values were substituted into the time-series. The final spring time-series is plotted in Fig. 2.4.

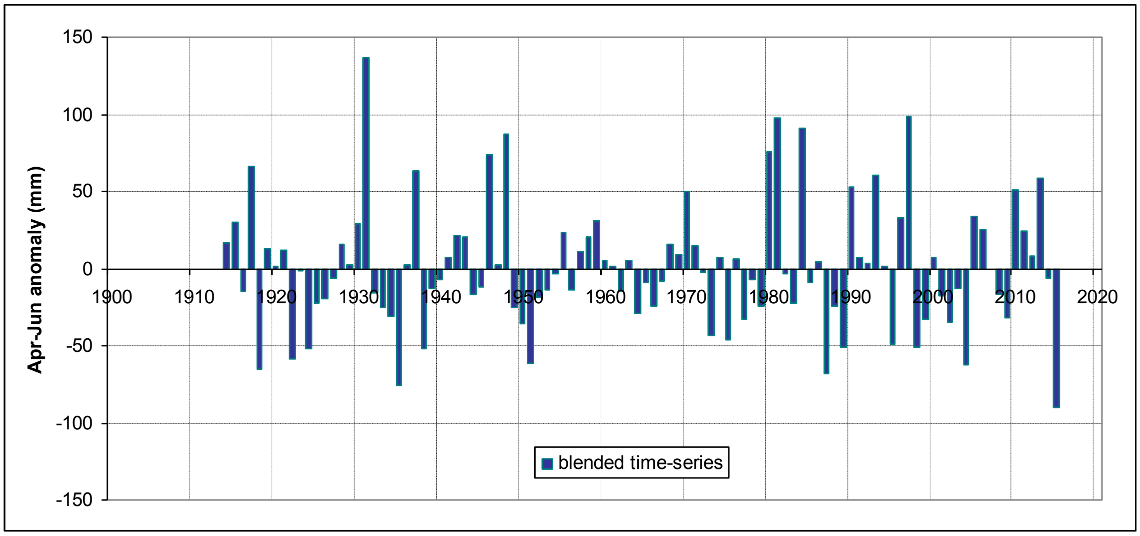


Figure 2.4 Blended spring precipitation anomaly (April-June) spanning the period 1914 to 2015.

Blended Fall-winter Anomaly

The method for deriving the blended fall-winter series $\{S_W\}$ is the same as described previously for the spring series. The 22-yr ma filter was used to de-trend the time-series and the anomalies calculated from (4). Figure 2.5 shows the scatter diagram of coincident values for each series; the correlation is strong positive with a correlation coefficient r = 0.89, which is slightly better than for the spring series. The final blended series is plotted in Fig. 2.6 and the cumulative probability distribution is shown in Fig. 2.7. The anomalies range from about -360 to over 430 mm. As the distribution function shows, there are roughly 10 occurrences of low rainfall winters, of 200 mm, or more, below the mean, each century (about once every 10 years, on average). Mean fall-winter rainfall for the past 39 years at St. Mary Lake is 690 mm.

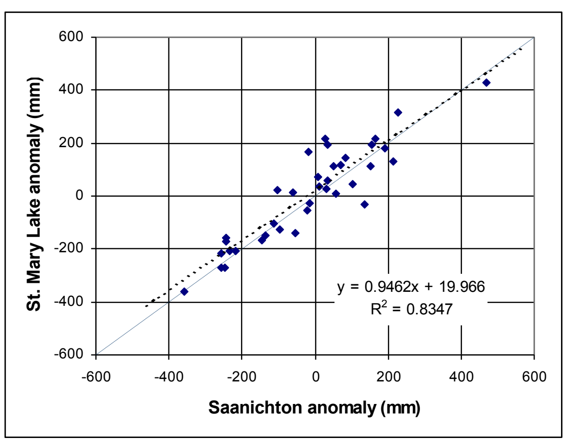


Figure 2.5 Correlation of fall-winter anomalies, r = 0.89.

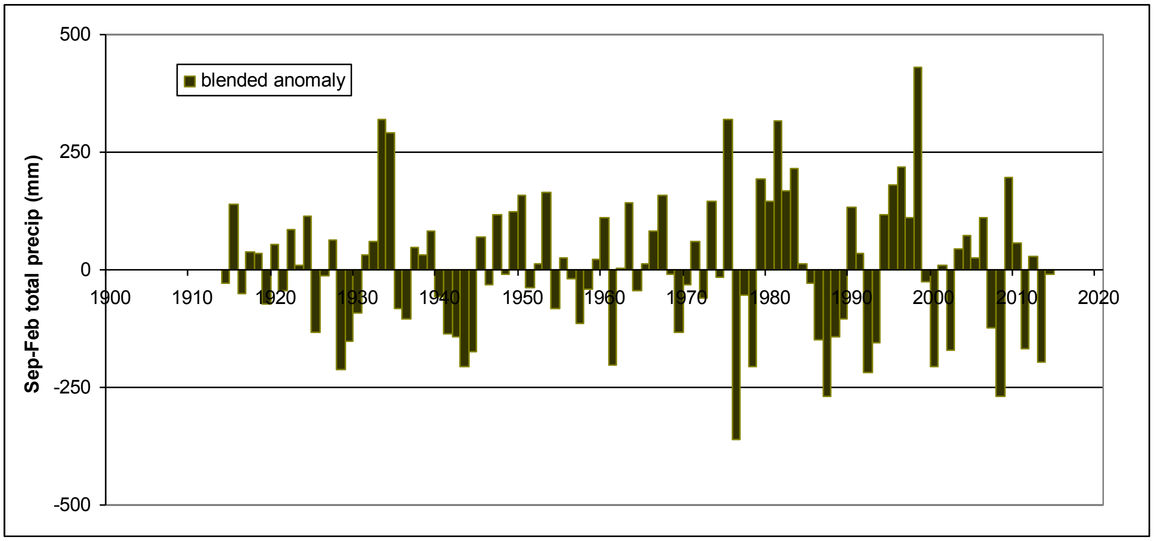


Figure 2.6 Blended fall-winter precipitation anomaly $\{S_W\}$ spanning the period 1914-2014. Note: in this case, the value plotted for a given year represents the 6-month sum beginning in September from the season *following* the dry spring.

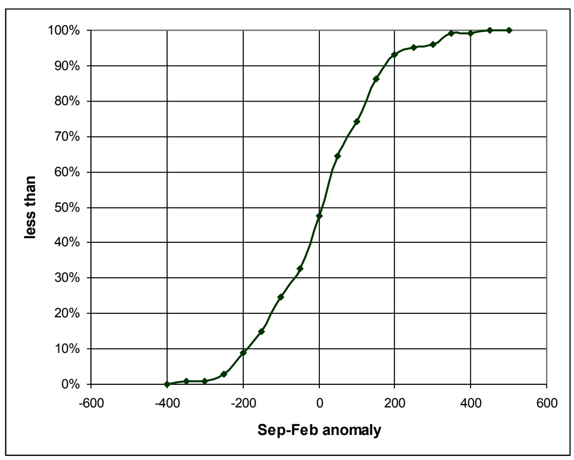


Figure 2.7 Cumulative distribution for the fall-winter precipitation anomaly.

Blended Annual Anomaly

The same procedure was followed for the annual time-series $\{P_A\}$ yielding the anomaly $\{S_A\}$ plotted in Fig. 2.8. Inspection of this graph suggests that the variance in the Saanichton signal is greater in the final 30-odd years than in the preceding years, and this is borne out in the statistics. The standard deviation for 1914-1975 is 144 mm vs 190 mm for 1976-2013. This difference is considered real at the 5% level of significance (probability at which chance alone would account for the difference). Accordingly, the Saanichton record has *not* been adjusted for the difference in variance, preserving the trend with time to larger fluctuations from year to year. In contrast, the variances for Saanichton and SML for the period of overlap are not significantly different, and the series have been blended as described previously for the other two series (Fig. 2.9).

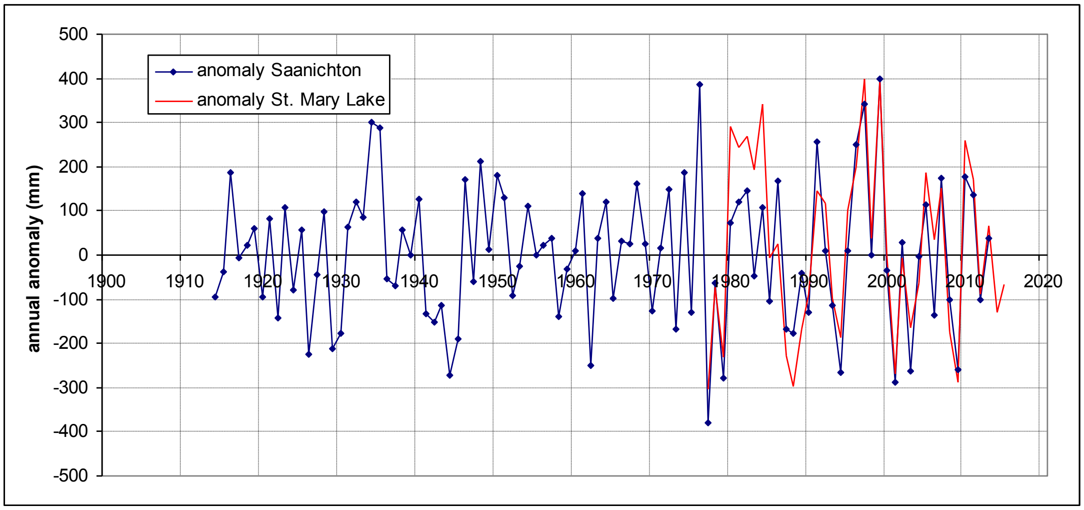


Figure 2.8 Annual precipitation anomaly $\{S_A\}$ for both stations.

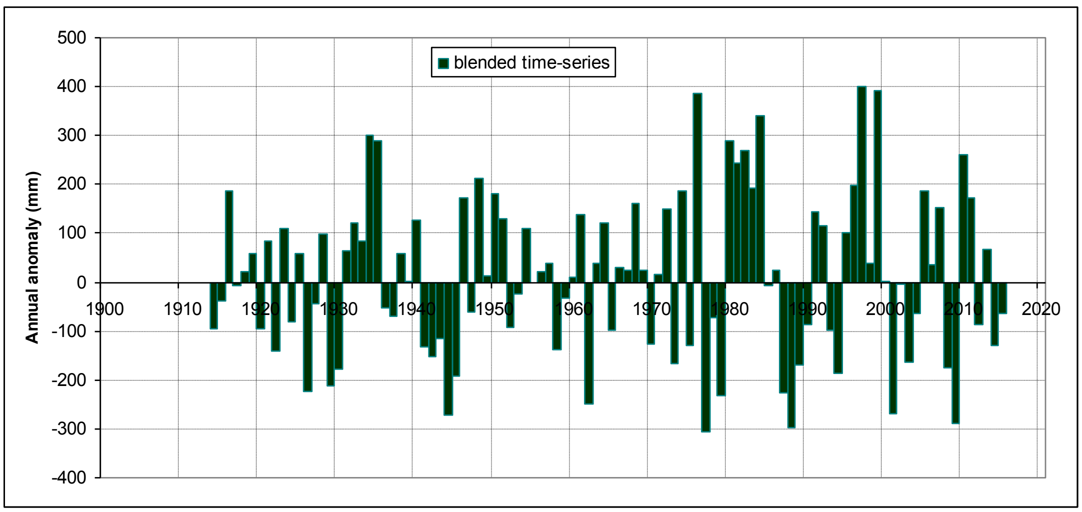


Figure 2.9 Blended annual precipitation anomaly $\{S_A\}$ (Aug-Jul) spanning the period 1914-2015. Note: the annual total plotted for a given year represents the 12-month sum from the preceding summer to the year specified.

3.0 DISCUSSION OF RESULTS

3.1 Spring Precipitation Anomaly

Inspection of the graph in Fig. 2.4 shows immediately that 2015 stands out as the year with the greatest spring rainfall deficit (below normal), by a considerable margin. Certainly, 2015 would have a conventional return period well in excess of 100 years. The 10 driest years are listed in Table 3.1, six of which occurred before the period of record at St. Mary Lake. The distribution of droughty springs suggests that such conditions are *not* becoming more frequent. Because the variance in the spring signal is stationary, it is also reasonable to expect that the degree of spring rainfall deficit (magnitude of the anomaly) is *not* increasing with time. 2015 was bad, but there is no indication in the data that such conditions will recur with less and less rain each time.

During the period of measurements at St. Mary Lake, the average spring rainfall was approximately 136 mm, with values ranging from a maximum of 230 mm to a minimum of 42 mm (in 2015). Prior to 2015, the lowest amount of spring rainfall recorded at the lake was 70 mm. The current max and min values represent a difference of about 68% of the mean value, showing that rainfall amounts in the period Apr-Jun vary considerably from year to year. The standard deviation is 44 mm (n=40).

Table 3.1 Rank-ordered rainfall anomaly (drought years). Greyed values occurred before 1976.

Ranked by spring anomaly				ranked by annual anomaly		
		Apr-Jun	Aug-Jul			Aug-Jul
		spring	annual			Annual
rank	Year	anomaly	anomaly*	Rank	year	Anomaly
		(mm/yr)	(mm/yr)			(mm/yr)
1	2015	-89.7	-65.1	1	1977	-304.9
2	1935	-76.1	288.7	2	1988	-297.9
3	1987	-67.9	-227.7	3	2009	-289.1
4	1918	-64.8	21.3	4	1944	-271.7
5	2004	-62.4	-63.2	5	2001	-269.1
6	1951	-61.9	128.9	6	1962	-248.7
7	1922	-58.3	-141.5	7	1979	-232.4
8	1924	-52.3	-80.1	8	1987	-227.7
9	1938	-51.5	57.3	9	1926	-224.3
10	1989	-50.9	-169.2	10	1929	-211.6

* years that contain the droughty spring.

3.2 Annual Precipitation Anomaly

The annual data are presented mainly to show that the spring droughty years are not correlated with years having low total precipitation over 12 months that contained the droughty spring. For example, the ranking in Table 3.1 shows that 2015 does not even occur in the 10 driest years (it is 36^{th}), and only one year, 1987, occurs in both rankings. The table also shows that six of the 10 driest years occurred since 1976, as well as 4 of the 5 most severe years, which is consistent with the trend of increasing variance with time noted in the previous section. These features are also evident in the graph in Fig. 2.9. Column 4 in Table 3.1 lists the annual totals for the years that did have droughty springs.

The lack of correlation is simply explained by the fact that a dry spring does not typically occur in conjunction with low rainfall during the fall-winter months that *precede* it.

3.3 Lake Refilling After a Droughty Spring - Conditional Probability of Not Refilling

From a water supply perspective, a critical question is what are the odds that precipitation in the fall-winter period, following a droughty spring, is insufficient to refill the lake. I have examined this question using the blended time-series for total precipitation from September to the following February, to estimate the conditional probability of a "critical" winter coinciding with a year featuring a spring drought.

The spring anomaly (from Fig.2.4 – plotted here as the solid red line) is super-imposed on the fall-winter anomaly in Fig. 3.1. These two series are clearly un-correlated (r = 0.12). As a result, we anticipate that coincidence of a low rainfall winter following a droughty spring is a rare event.

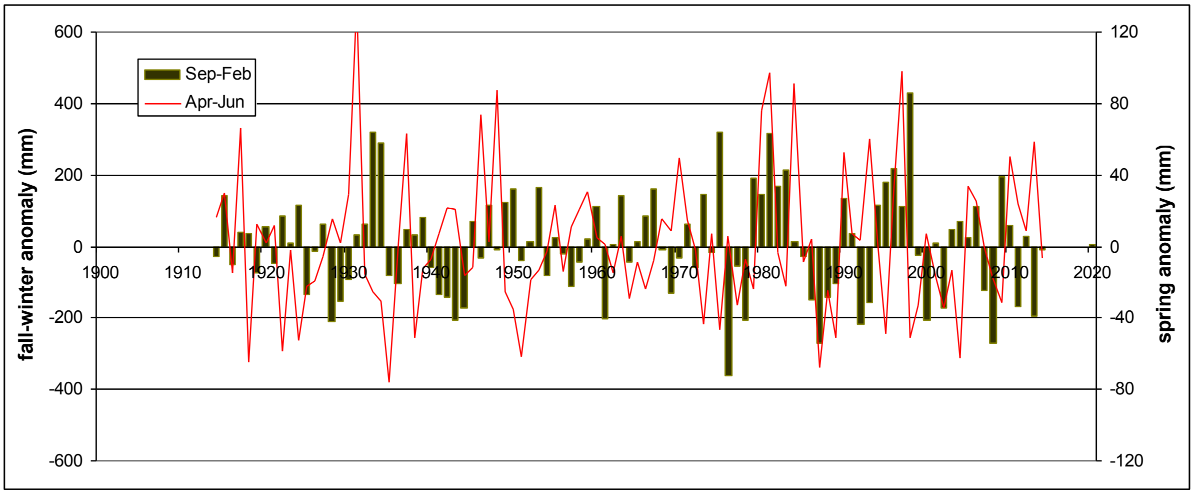


Figure 3.1 Comparison of the fall-winter anomaly with the spring anomaly.

In order to quantify the conditional probability it is necessary to specify criteria for each anomaly. For the spring anomaly, I have set the criterion at -45 mm, which is an amount below which precipitation may be expected about 10% of the time. This is a relaxed criterion (2015 was -90 mm) and chosen so as not to eliminate many potentially matching events.

A criterion for the fall-winter anomaly is a little more difficult. One approach is to examine the reliable water level records from 2007-2015 and extract the rainfall amount that was required each year to fill the lake – in this case, refilling back to 40.70 m. The results were a little unexpected in that a clear relationship between the draw down in the lake, the time to refill, and the corresponding amount of precipitation (or inflow) did not emerge. These data (Fig. 3.2) suggest that a safe refilling value is about 400 mm. Sometimes the lake refills with considerably less rainfall; however, 400 mm represents a conservative value and has been used here. Since the mean = 690 mm, the corresponding anomaly is -290 mm. Again, I have used a slight relaxed criterion of -250 mm to include as many events as possible.

The conditional probability $Pr(S_W< -250|S_S<-45)$ was calculated by finding the number of matching events: there turned out to be only one, 1987 (event 3 in Table 3.1). The fall-winter anomaly was -270 mm, following the spring anomaly of -68 mm (not very severe compared with 2015). Using the criterion of $S_S<-45$ mm yielded 12 occurrences in 101 years. The conditional probability thus becomes $1/101\times 12/101$ or 0.0012. This corresponds to a return period of about 850 years. In fact, the probability is actually smaller (longer return period) since the criterion for S_S was not particularly severe in terms of spring draw down.

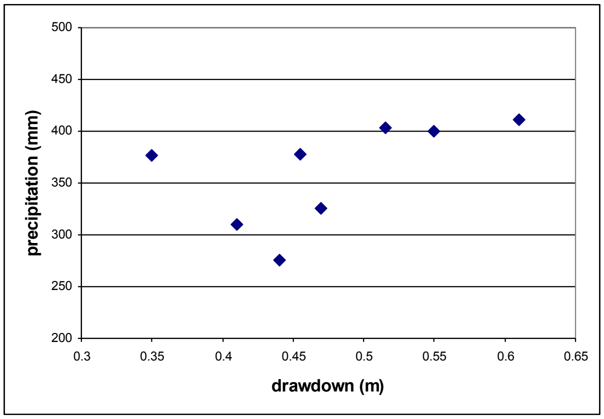


Figure 3.2 Scatter diagram of precipitation to refill St. Mary Lake versus draw down.

Admittedly, this is all pretty rough, but it seems clear that the danger of not refilling the lake after a droughty spring – even one as severe as 2015 – is minimal.

3.4 Long-term Trends

The 22-yr ma annual precipitation time-series (Fig. 3.3, the same as in Fig. 2.1 – upper panel) clearly shows that there has been, approximately, a 200 mm increase in total rainfall over the last 100 years. This increase was most rapid, and reasonably steady, in the early part of the last century, up to about 1960; thereafter, it appears to be more gradual. The linear regression line has a slope of 2 mm/yr.

Figure 3.3 also shows the same graphs for the fall-winter (Sep-Feb) series, and for the spring (Apr-Jun) time-series. The character of the fall-winter time-series is similar to the annual series, except that the increase over 100 years is slightly lower, about 140 mm (consistent with the slope of the linear regression line of 1.4 mm/yr). The Apr-Jun series also shows an increase, of about 40 mm, consistent with the regression line slope.

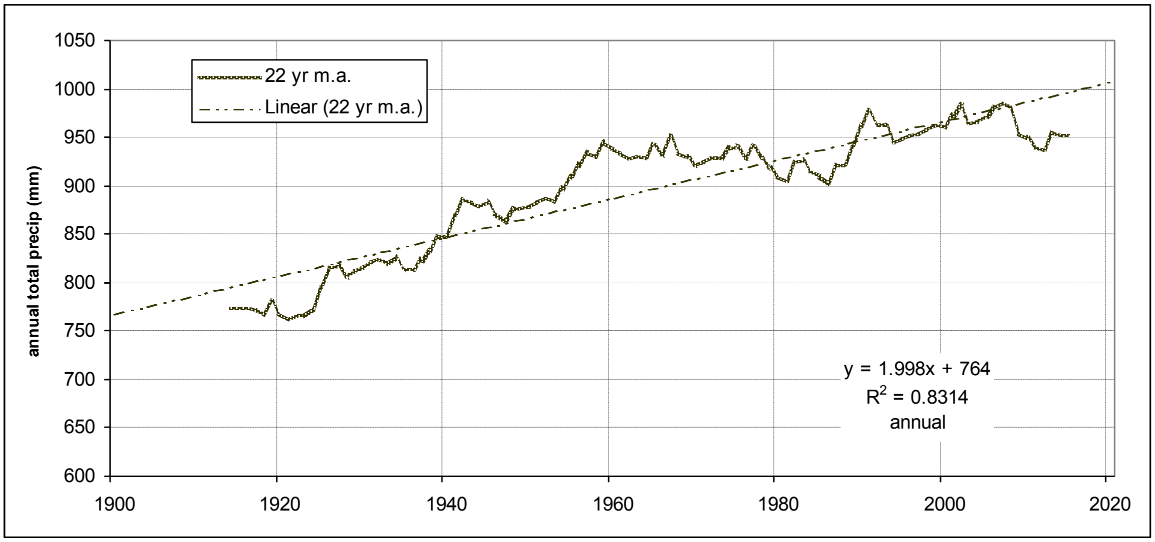
These results are convincing: the climate has become increasingly wetter over the past century. Most of the increase occurs during the fall-winter season, but all seasons are likely receiving greater rainfall amounts. (The period July-September has not been examined in this study.)

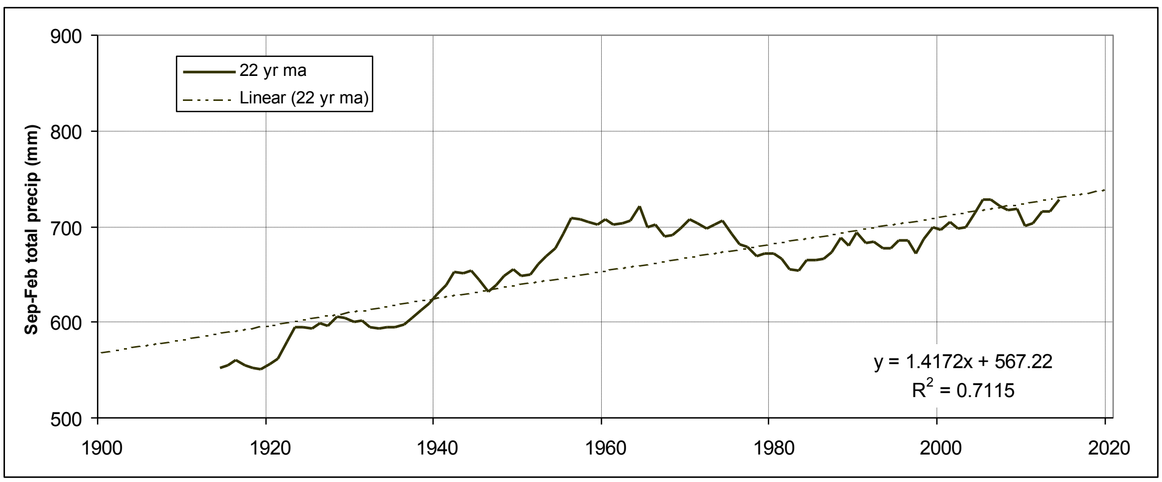
It is tempting to also infer a low-frequency oscillation in the data, with a period of approximately 50 to 60 years (~ 1950 to ~ 2000). It begins with a dryer cycle in the fall-winter series, followed by a slightly wetter cycle. The spring series exhibits a similar oscillation, but it is almost exactly out of phase with the winter cycles. It is certainly not clear from the data after 2000 that such cycles are about to occur again.

3.5 Analysis of Variance

Inspection of the annual anomaly time-series (Fig. 2.9) and the fall-winter time-series (Fig. 2.6) shows an increase in variability between the first 40 years of the record and the final 40 years. A similar increase in variability is not so evident in the spring anomaly (Fig. 2.4).

To test this observation, the variances of the time-series were calculated for the beginning and ending 40 years of each record and compared using the standard F-test. The results, expressed as standard deviations, are shown in Table 3.3. The test applied is that $s_1^2 > s_2^2$; that is, that the variance of the last 40 years is greater than for the first 40 years at a specified level of significance (1%).





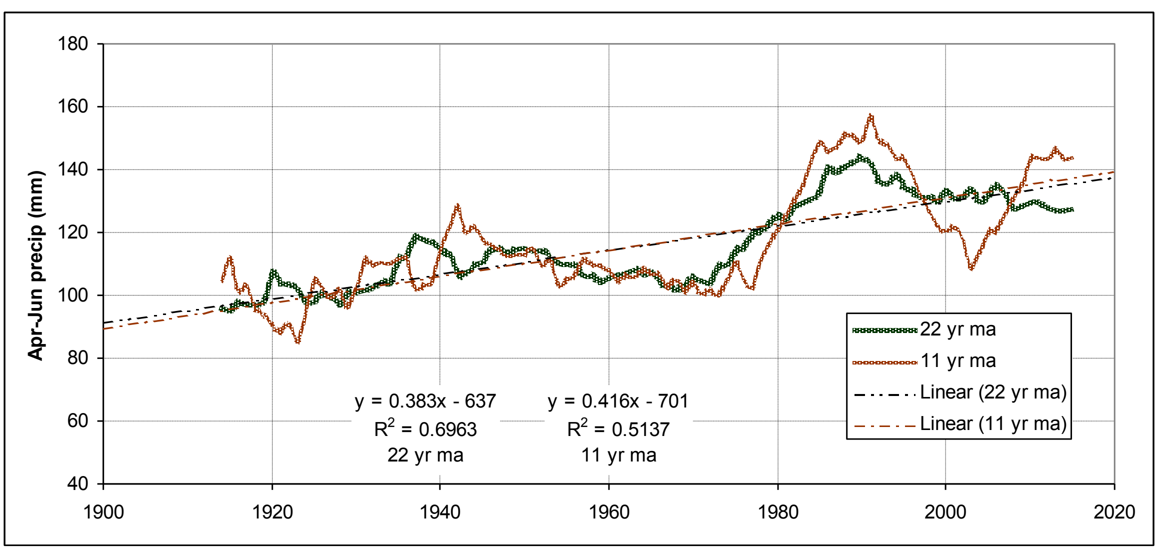


Figure 3.3 Time-series of the moving average applied to $\{P_A\}$, $\{P_W\}$, and $\{P_S\}$.

These results confirm the visual observations of the variability: for the annual and fall-winter anomalies the F-ratio[4] exceeds the 1% level of significance and it is likely that the differences are real. The opposite is true for the spring anomaly, which would be expected by simply comparing the two standard deviations.

Table 3.3 Standard deviations and F-ratio results for precipitation anomaly.

date range	parameter	Sep-Feb	Apr-Jun	Annual
1976-2013	s_1	180.8	44.0	210.2
1914-1955	s_2	119.2	42.2	138.3
1976-2013	n_1	38	38	38
1914-1955	n_2	42	42	42
	F	2.30	1.09	2.31
	1% ratio	2.05	2.05	2.05

Together with the trends in mean precipitation, these results suggest that rainy seasons at St. Mary Lake have become wetter over the past 100 years, and that the year-to-year *changes* in precipitation amounts have also increased (greater variability). The spring rainfall record also indicates a trend to increasing amounts, but the year-to-year *changes* do *not* appear to be increasing, or decreasing.

3.6 Accuracy

These analyses depend, of course, on how closely the SML record matches the Saanichton record. Figure 3.4 shows the marginal distributions for the differences between the records for each station, for the spring anomaly and for the fall-winter anomaly. Eighty-seven percent (87%) of the 38 data points lie within ±20 mm for the spring series. Since mean rainfall during that period is 136 mm, 87% of the data points fall within 15% of the mean. For the fall-winter series, 81% of the data fall within ±80 mm, or about 12% of the 690 mm mean. Thus, it appears that the amplitudes of the anomaly time-series, for the overlapping period, agree to better than 15% for the great majority of observations (for 30 out of 37 observations).

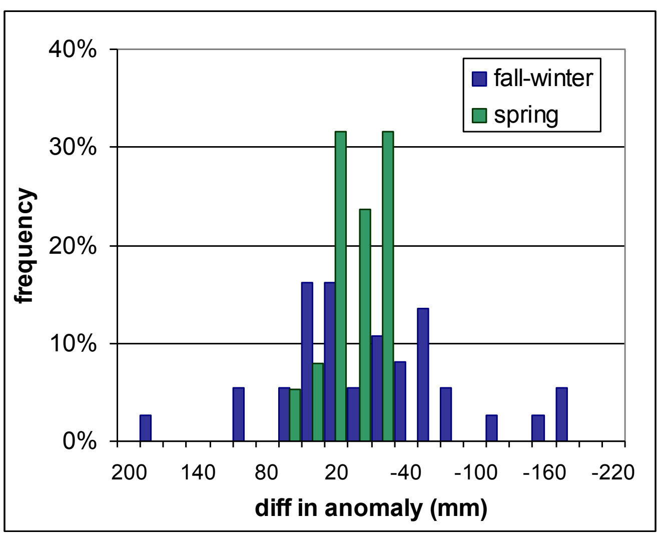


Figure 3.4 Marginal distributions of the difference between precipitation anomalies (Saanichton – SML).

[4] $F = s_1^2/s_2^2$

3.7 Sensitivity to the Averaging Window

As noted earlier, the choice of a 22-yr ma width was rather arbitrary. A second spring (Apr-Jun) precipitation anomaly series was derived with an 11-yr ma filter for comparison with the first time-series. The de-trending time-series are compared with the blended monthly data in Fig. 3.5. As expected, the low-frequency fluctuations are larger than with the 22-yr filter, although the linear regression lines are virtually the same, with slopes of 38 mm/yr *vs* 42 mm/yr (Fig. 3.3, bottom panel). The derived anomalies, compared in Fig. 3.6, tend to be slightly larger on the negative (droughty) side than on the positive (wetter) side from the 11 yr ma; however, the differences are small, approximately 10% of the value. These characteristics are borne out in the probability distributions (Fig. 3.7).

The ranked droughty years are listed for both filters in Table 3.2, and are identical for ranks 1 through 4. There is only one year that is different between the columns; otherwise, it is the order that is slightly changed because of the differences in the arithmetic. All values, excluding 2015, range from approximately -45 to -70 mm. Thus, the identification of the most extreme events is basically the same. Importantly, the results for the conditional probability of a droughty spring followed by a dry winter are unchanged: 1987 is the only year with coincident dry conditions in both seasons, and the conditional probability for the 11-yr ma is slightly lower (0.00098) because there are only 10 occurrences of dry springs < -45 mm compared with 12 previously.

Finally, the size of the ma filter obviously makes small changes in the magnitude of the anomalies, but they are not large enough, or consistent enough, to change the main conclusions reached previously.

Table 3.2 Comparison of rank-ordered rainfall anomaly (drought years) for each moving average filter.

rank	year	11-yr ma	year	22-yr ma
1	2015	-101.7	2015	-89.7
2	1935	-76.8	1935	-76.1
3	1987	-76.1	1987	-67.9
4	1918	-64.0	1918	-64.8
5	1951	-62.0	2004	-62.4
6	1989	-59.0	1951	-61.9
7	1995	-57.3	1922	-58.3
8	1924	-47.9	1924	-52.3
9	2004	-46.4	1938	-51.5
10	1998	-46.1	1989	-50.9

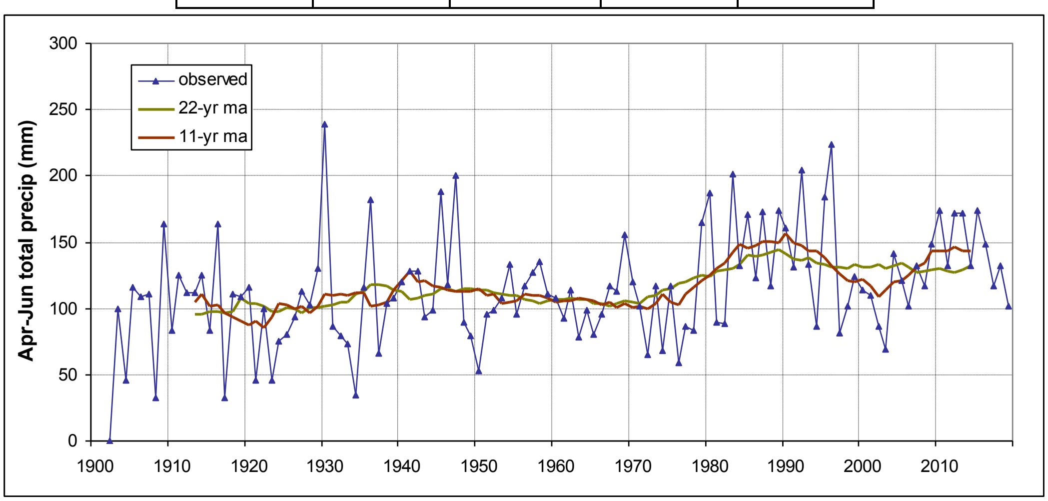


Figure 3.5 Comparison of the two moving average time-series with the observed blended time-series.

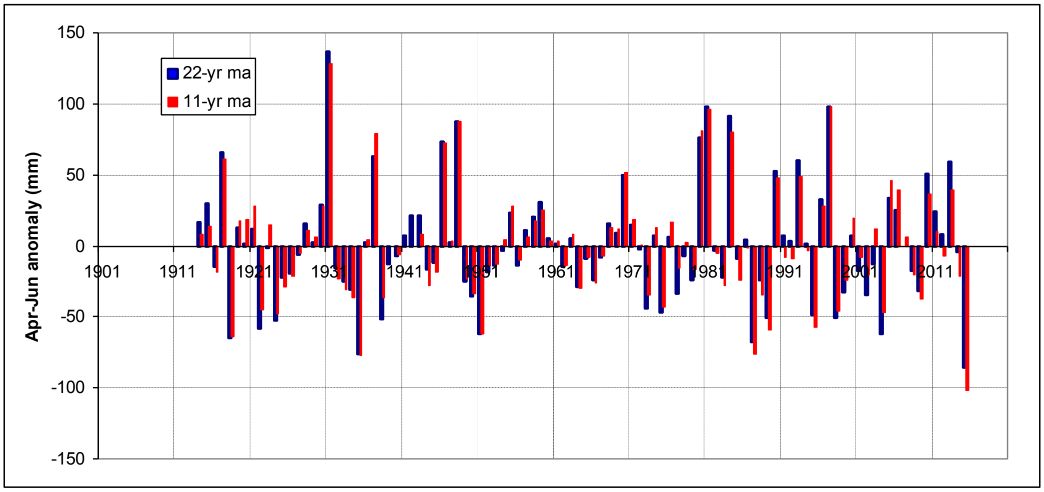


Figure 3.6 Comparison of the Apr-Jun precipitation anomalies derived from each filtering method.

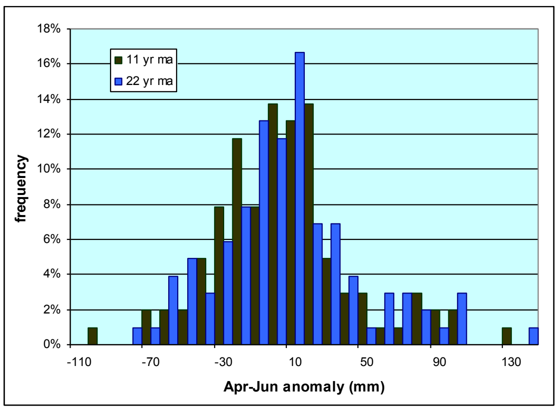


Figure 3.7a Comparison of marginal distributions of the Apr-Jun anomalies.

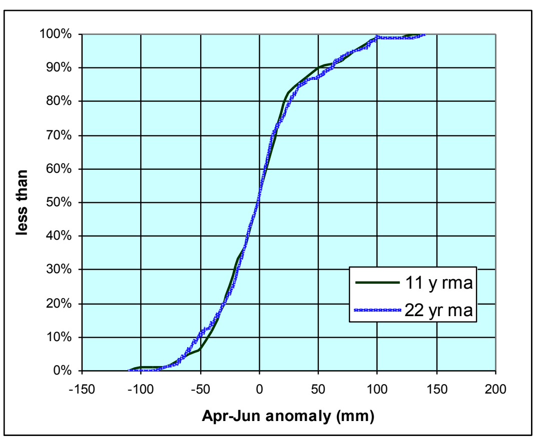


Figure 3.7b Comparison of cumulative distributions of the Apr-Jun anomalies.

4.0 CONCLUSIONS

Comparison of the overlapping adjusted precipitation time-series for Saanichton with the St. Mary Lake (SML) record (mean and variance) shows that they are similar enough that the 100-yr Saanichton data can be used to construct a proxy long-term record for St. Mary Lake. This proxy was created by simply blending the two records with the SML data used directly for 1976-2015. Analysis of this blended record leads to the following conclusions:

1. The 2015 spring drought (April through June) was by far the most severe in the 100-yr record. It has a return period well in excess of 100 years.

2. Droughty springs occur throughout the record. There is, however, *no* indication that they are becoming more frequent or more severe, on average.

3. The odds that a droughty spring will be followed by a droughty fall and winter, leading to a shortfall in the lake refilling, are long: of the order of one in 1000.

4. Both annually, and total rainfall over the fall and winter, our climate is becoming wetter. The annual data suggest an increase of about 200 mm in the past century, or about 20% of the current annual total of 965 mm.

5. The data also suggest that the year-to-year variations in total and fall-winter rainfall (the change from one year to the next) are increasing compared with 100 years ago.

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[2] Mekis, É and L.A. Vincent, 2011. An overview of the second generation adjusted daily precipitation dataset for trend analysis in Canada. *Atmosphere-Ocean*, 49 (2), 163-177.