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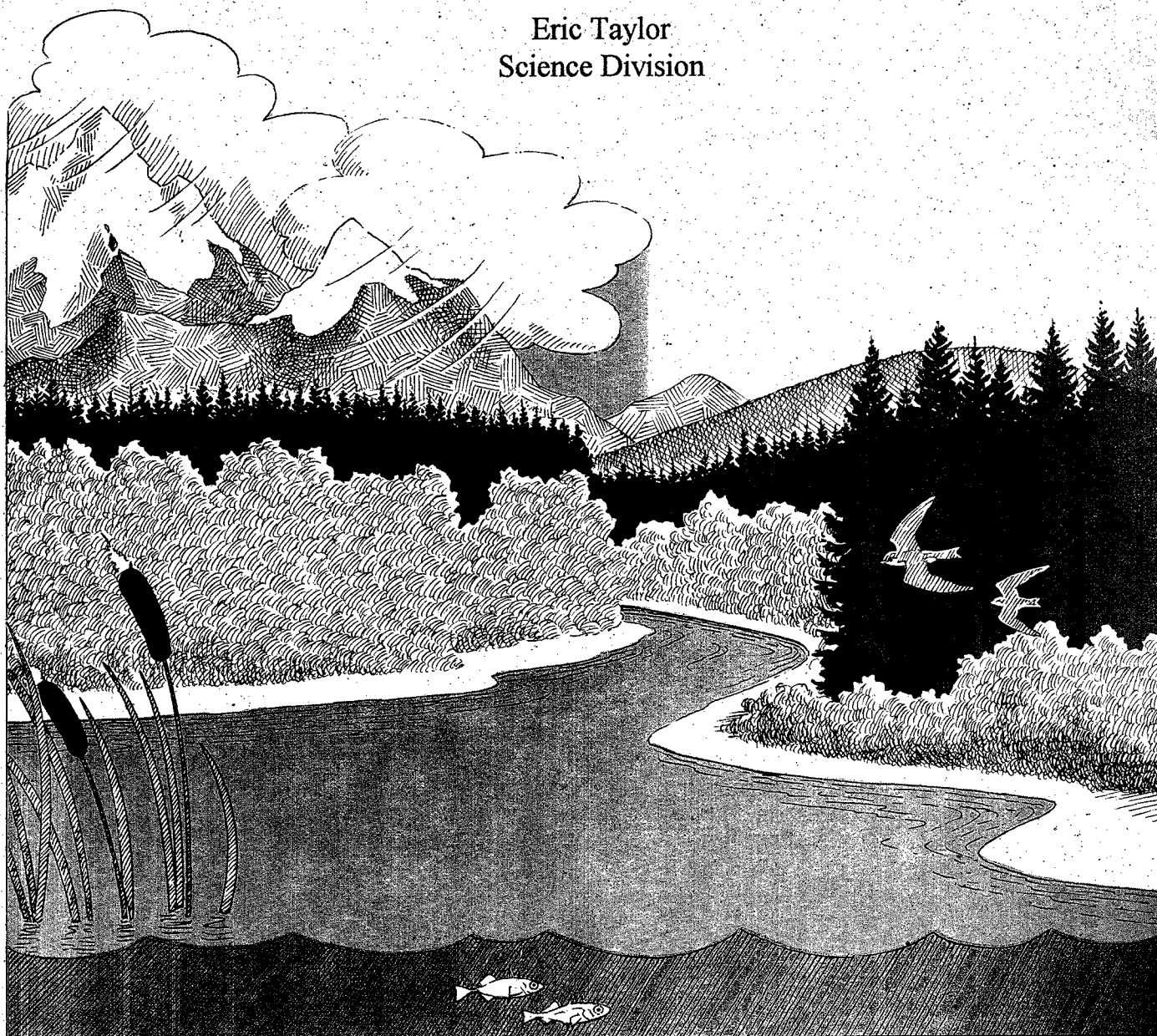
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**The Use of Equatorial Indices for
Winter Climate Prediction in the Yukon**

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The Use of Equatorial Indices for Winter Climate Prediction in the Yukon

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ABSTRACT

Winter temperatures and precipitation at three sites in the Yukon are compared to the monthly sea surface temperature of the eastern equatorial Pacific and the monthly Southern Oscillation Index (SOI) occurring in the previous summer and autumn. The highest correlations between winter Yukon temperatures and these equatorial indices occur with the August SOI and the September equatorial sea surface temperatures. The highest correlation between winter Yukon precipitation and the equatorial indices occur with the August SOI and the October equatorial sea surface temperatures. Linear relationships between winter Yukon temperature and both the SOI and equatorial sea surface temperatures are developed as a winter temperature forecasting tool.

1. INTRODUCTION

This paper explores the use the Southern Oscillation Index (SOI) and equatorial sea surface temperatures as a tool in forecasting the winter climate in the Yukon (figure 1). The SOI is the standardized difference in sea level pressure between Tahiti and Darwin. This index is linked to the cyclical warming of the ocean surface near the equator in the eastern Pacific, known as El Niño. Negative values of the SOI generally occur during this oceanic warming.



Figure 1. The Yukon with the locations of the three climate stations used in this study.

Previous work has shown that the winter climate in most of the Yukon is related to El Niño (Ropelewski and Halpert 1986; Clark 1990, Shabbar 1993). Ropelewski found that the December through March season is generally milder during El Niño events in the Yukon and that the January temperature of Whitehorse is most highly effected.

A possible cause for this link between equatorial climate and Yukon climate is that the warmer water along the equator increases the north-south atmospheric temperature gradient across the north Pacific. This in turn strengthens the westerly jet stream in the middle atmosphere and results in a stronger push of mild Pacific air over northwestern North America during the winter, including the Yukon (Kousky, 1991, personal communication).

This paper builds on this previous work by developing a forecast tool to help predict winter temperature and precipitation anomalies in the Yukon based on equatorial sea surface temperatures and the SOI from the previous summer and autumn.

2. DATA

Monthly values of the SOI from 1951 to 1993 and sea surface temperature anomalies (SST) from the Niño 3 region from 1970 to 1993 were obtained from the Climate Analysis Center, Washington, D.C. The Niño 3 region is a 10 degree latitude wide band along the eastern equatorial Pacific from 150° West to 90° West longitude.

Table 1. Yukon climate stations from which temperature and precipitation were analysed.

Climate Station	Location	Elev. (m)
Whitehorse	60° 43' N, 135° 04' W	703
Watson Lake	60° 07' N, 128° 49' W	690
Mayo	63° 36' N, 135° 53' W	504

Monthly average temperatures and precipitation from three Yukon climate stations having climate records since 1951 were obtained from the Canadian Climate Centre, Downsview, Ontario. Locations and elevations of these stations are given in Table 1.

Winter temperatures in this study are the average of the monthly temperatures of December through March. Winter precipitation is the sum of the monthly precipitation for these months

3. ANALYSIS

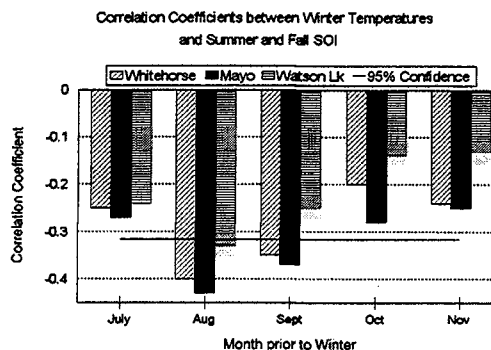
The initial objective was to find the summer or autumn month(s) during which there was a significant correlation between the equatorial indices and following winter climate. Correlation coefficients were generated between the winter climate variables and the monthly SOI and Niño 3 region SSTs of the five to seven months preceding the winter period. Correlation coefficients were also generated between the two to four-month averages of these monthly SOI and SSTs and the winter temperature and precipitation.

The second objective was to use linear regression to develop relationships between Yukon climate and the summer and fall equatorial indices where significant correlations existed.

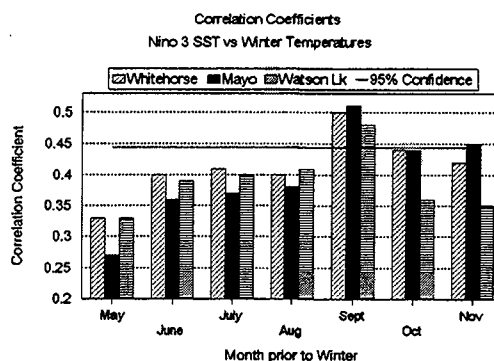
a) Temperature

Winter temperature at the three climate sites is negatively correlated to the monthly SOI for all summer and fall months (Figure 2, top).

The best correlation is between winter temperatures and the previous August SOI. The August correlation coefficients range from -0.33 at Watson Lake to -0.43 at Mayo. These are statistically significant at the 5% level. The correlations between winter temperature and SOI values from the months of October and November are markedly lower than those in August. This is a non-intuitive result, since climate conditions occurring in the December through March period



N=39



N=20

Figure 2 Correlations between winter Yukon temperatures and the Southern Oscillation Index (top) and SST from the Niño 3 region (bottom) from the previous summer and fall. The horizontal lines indicate the value for which the correlation coefficient becomes significant at the 5% level.

would be expected to be most highly correlated with the SOI of the most recent month, November.

Winter temperatures at the three sites are positively correlated to SSTs in all summer and fall months preceding the winter (Figure 2, bottom). The highest correlation is between September SSTs and Yukon winter temperatures. The September correlation coefficients range from 0.48 at Watson Lake to 0.51 at Mayo. All September correlations are statistically significant at the 5% level.

These results reveal a one-month lag between the months of highest correlations of Yukon winter temperatures and equatorial SSTs and SOI. This may be due to the dependence of the

SSTs on the wind field, and therefore the SOI, at the equator. Anomalous westerly winds tend to move more warm water into the eastern equatorial Pacific. This is likely due an eastward-propagating equatorial Kelvin wave initiated by these anomalous westerly winds. This Kelvin wave takes about two months to travel from New Guinea to South America (Gill, 1982). This relatively slow speed could be the explanation for the time lag between SOI and SST correlations. Similarly, it is reasonable to expect that there will be a time lag between the onset of anomalous easterly winds at the equator and cooler equatorial SSTs caused by increased upwelling along the northwest coast of South America.

Table 2 shows the results of using linear regression to estimate a relationship between Yukon winter temperature and the SOI or SST. The August SOI or the September SST is chosen as the independent variables due to their better correlations with winter temperatures. The winter temperature anomaly at each climate site is the dependent variable. Plots of the regression lines and data for Whitehorse are shown in Figures 3 and 4. As the correlation coefficients are not large, less than 25% of the variance in winter temperatures is explained

Table 2. Equations linking equatorial indices and winter temperature at three Yukon climate sites, based upon linear regression. T is the winter (December through March) temperature anomaly ($^{\circ}\text{C}$) at each site, SOI is the standardized Southern Oscillation Index of the previous August, and SST is the anomaly ($^{\circ}\text{C}$) in the sea surface temperature in the Niño 3 region of the equatorial Pacific of the previous September. Correlation coefficients (r) vary slightly from those displayed in figure 2 where the sample size (N) is sometimes smaller. p is the significance level.

Site	Regression Equation	r	N	p
Whitehorse	$T = -0.079 - 1.4 * SOI$	-0.42	41	.007
	$T = 0.092 + 2.0 * SST$	0.49	22	.019
Mayo	$T = 0.025 - 1.5 * SOI$	-0.43	39	.007
	$T = 0.37 + 2.1 * SST$	0.51	20	.020
Watson L.	$T = 0.38 - 0.95 * SOI$	-0.34	40	.034
	$T = 0.32 + 1.5 * SST$	0.48	21	.028

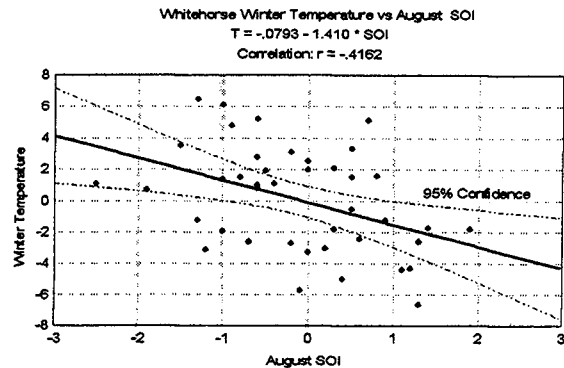


Figure 3 Scatter plot of the Whitehorse winter temperatures as a function of the August SOI. Regression lines with 95% confidence limits are also plotted.

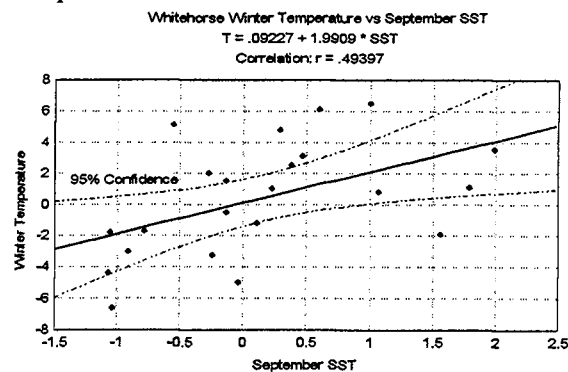


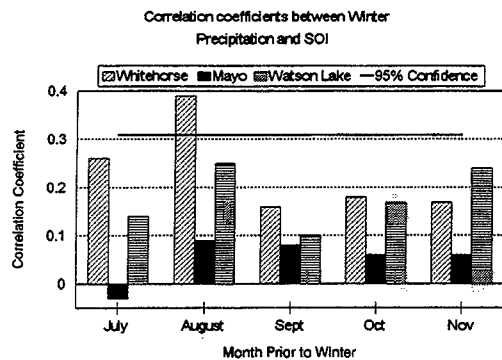
Figure 4. Scatter plot of the Whitehorse winter temperatures as a function of the September SST from the Niño 3 region. Regression lines with 95% confidence limits are also plotted.

by these equatorial indices at all three climate sites.

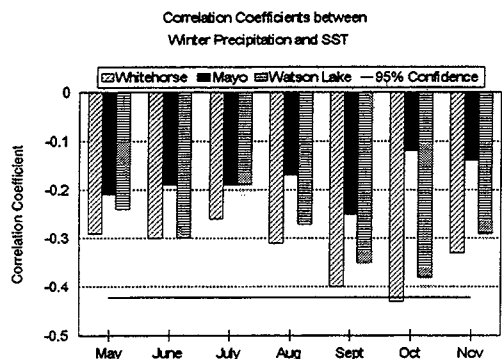
Correlations of the average of several months of summer and fall SOI or SST with winter Yukon temperatures were not as high as the highest single month correlations and are therefore not shown here.

b) Precipitation

The correlation between winter precipitation at the three Yukon climate sites and the equatorial indices is lower than that for Yukon temperature. Correlation coefficients between winter precipitation and summer and fall SOI are all positive (Figure 5, top) except for one near-zero correlation in July for Mayo. The highest correlation



N=41



N=22

Figure 5 Correlation coefficients between winter Yukon precipitation and the SOI (top) and the SST from Nino 3 region (bottom) for the summer and fall months prior to the winter. The horizontal line in the graph indicates the value of the correlation coefficient at which correlation is significant at the 5% level.

coefficient between winter precipitation and SOI is 0.39 at Whitehorse for the August SOI. Watson Lake also showed a peak in August (0.25), although the November SOI is almost as high. Only the August SOI correlation with Whitehorse winter precipitation is significant at the 5% level.

Correlations between winter precipitation and summer and fall SSTs is higher than with SOIs (figure 5, bottom). All correlations are negative. The only correlation coefficient that is significant at the 5% level is between winter precipitation at Whitehorse and the October SST (-0.43). Watson Lake also shows a peak in October with an correlation coefficient of -0.38. There is only a

weak correlation between SST and Mayo winter precipitation.

Due to the generally poor correlation coefficients between winter precipitation and the summer and fall equatorial indices, and the resulting relatively small amount of precipitation variance explained by the equatorial indices, linear regression was not used to determine relationships between the variables.

4. SUMMARY AND CONCLUSIONS.

The SOI of the previous summer and fall is negatively correlated to winter temperatures (December through March) in three climate sites in the Yukon. August SOIs have the best correlation to subsequent winter temperatures. Correlation coefficients between temperature and August SOIs varies between -0.34 and -0.43.

The SST in the Niño 3 region of the equatorial Pacific of the previous months is positively correlated to winter temperatures in the Yukon. September SSTs have the best correlation to subsequent winter temperatures. Correlation coefficients between winter temperature and September SSTs varies between 0.48 and 0.51.

Linear relationships were developed between winter temperature and both SOIs and SSTs. All relationships show that negative SOIs or positive SSTs in the previous summer tend to result in warmer Yukon winters, with the opposite also being true. The variance explained by these equatorial indices is not large, but these relationships can be used as one tool in forecasting the winter temperature at the three Yukon sites.

The correlation between the equatorial indices and Yukon winter precipitation is not as high as the winter temperature correlations. Correlation coefficients between winter precipitation and SOI varies between near zero to 0.39, with the highest correlations occurring with the August SOI.

Correlation coefficients between winter precipitation and SSTs varies between -0.12 and -0.43, with the highest correlations occurring in with the October SST. Due to the generally small amount of precipitation variance explained by the equatorial indices, regression methods to estimate a linear relationship between the variables were not attempted

The cause of the time lag of up to 4 months between the most highly correlated summer and fall equatorial indices and the Yukon winter temperatures is not well understood. Warming of the sea surface at the equator appears to be linked with warming in the Gulf of Alaska. This warming would likely result in a milder winter climate in the Yukon. However, a cursory analysis of sea surface temperature anomalies along the west coast of North America does not reveal a significant time lag between warming at the equator and at 50°N.

Further work to expand this analysis into other areas of northwestern North America would be beneficial.

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