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Winter Temperature Variability Across Alaska During El Nino Events

John Papineau

WFO Anchorage

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Introduction

Air temperatures in Alaska during the winter months are highly variable on a variety of timescales, ranging from weeks to months. Due to the large north-south and east-west dimensions of the state, and the presence of complex terrain, there are considerable spatial variations as well. Both types of variability are evident during El Nino events. Figure 1 shows several examples of seasonal (Nov-Mar) temperature variability during six different El Ninos. The magnitude of the anomalies in Figure 1 have been scaled to each stations 30 year mean (1971-2000), hence interior locations typically have larger anomalies than maritime sites. There is clear evidence that at any given location, El Ninos do not produce consistent temperature patterns (anomalies) from one event to the next.

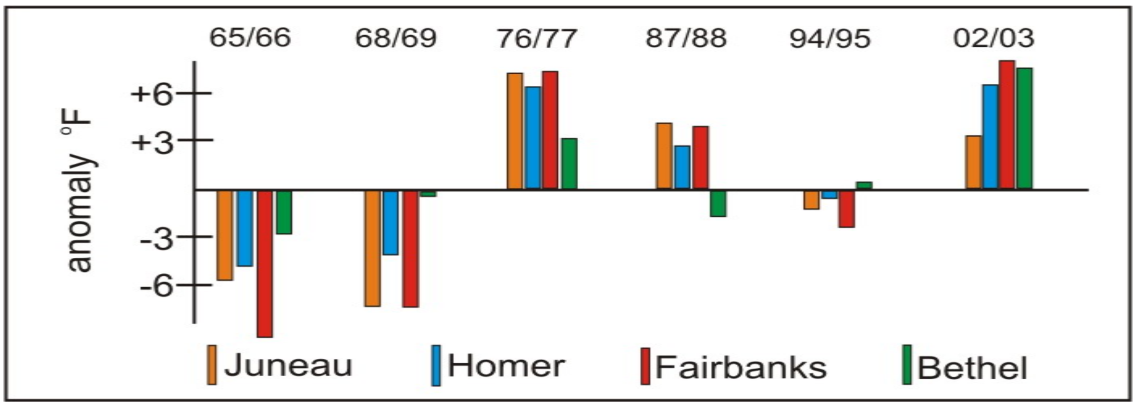

Figure 1: Seasonal temperature anomalies for six El Nino's

This paper will attempt to discuss why some El Ninos produce warm temperature anomalies and other El Ninos near normal temperatures, and on occasions, cooler than normal temperatures. In addition, during any given El Nino, temperatures on the <u>weekly</u> or <u>monthly</u> timescale display considerable variability as well. Even during very warm El Ninos, like the 2002-2003 event, there were periods in which temperatures were near or below normal. Thus a goal would be to determine what controls this intraseasonal variability.

El Nino's occur when warmer than normal sea surface temperatures (SST) migrate from the equatorial western Pacific into the equatorial central and eastern Pacific. This body of warm water often extends several hundred feet deep and represents a large transfer of energy. Note that rainfall is typically enhanced over this same region. During an El Nino easterly equatorial winds are usually replaced by westerly winds. El Ninos also generate a stronger than normal subtropical jet stream (250 mb) over the eastern Pacific and southwestern North America.

In the mid-latitudes El Ninos are characterized by enhanced ridging over the eastern Gulf of Alaska and western Canada, coupled with a deeper than normal Aleutian low that is shifted toward the southeast (when compared to its climatological position). Enhanced ridging over the eastern Gulf of Alaska and Canada during the winter months typically increases the frequency that warm moist air is transported northward along the west side of the ridge.

This paper is organized into six major sections. After a brief overview of methodology, a discussion of seasonal temperature patterns is examined. The discussion is then followed by a review of monthly temperature variability, and then an example of a 'cool' El Nino. Next the all important topic of seasonal forecasting is explored. The final section is a summary of the paper's most important points.

Data & Methodology

An important consideration in this type of climate study is the length and quality of temperature observations in Alaska. Routine observations were begun in the early part of the 20^{th} century at a handful of sites in Alaska; however, it was not until the early to mid 1950's that a true 'network' that would allow any type of climate study was established. Hence the time period under consideration in this paper begins in mid 1950's and extends through spring of 2004. Temperature anomalies used throughout this study are based on average monthly values which may then be used to construct seasonal means. The base period for 30 year means is 1971-2000. A total of 18 stations representing a good cross section of the state's climate zones are used in this analysis.

Despite several decades of intense research, the climate community cannot agree on a specific criteria or index for El Ninos (all ENSO events). Historically the most commonly used index has been the Southern Oscillation Index (SOI- of which there are several varieties), a measure of average monthly surface pressure difference between Tahiti and Darwin. A negative SOI indicates an El Nino while a positive value corresponds to a La Nina. Another index is the Nino3.4 which is based on average monthly sea surface temperature (SST's) anomalies in the equatorial central and eastern Pacific Ocean (base period is 1971-2000). The Multivariate ENSO Index, MEI, is a less commonly used index that uses input from six meteorological and oceanographic fields, including winds, temperatures, cloud cover, and SST's.

These three indices are not perfectly correlated. The agreement on strong El Ninos and La Ninas is good, but deteriorates for moderate to weak events. For this study Nino3.4 was used as the primary index with occasional reference to the two other indices. In order to determine whether an El Nino occurred, Nov. through Mar. SST anomalies are averaged to derive a seasonal value. A seasonal anomaly of $+0.5^{o}C$ or greater is indicative of an El Nino (see Trenberth 1997 for his definition of El Nino). The 15 warm events (listed below), that occurred between 1955 and 2004 are the focus of this study. Both concurrent and leading indices are used. Since the El Nino of the winter of 1957/1958 is the first event for which there are comprehensive observations of temperature across Alaska, the subsequent analysis ranges from November 1957 through March 2004.

This paper also makes reference to the Pacific Decadal Oscillation (PDO) index, which is based on SST anomalies in the extratropical North Pacific. SST anomalies located in the middle of the North Pacific (centered near $40^{o}N$, $160^{o}W$) are usually out of phase with SST anomalies in the Gulf of Alaska and along the west coast of North America. Note that the PDO index is not a SST anomaly; it is a statistical value that represents SST anomalies over a very large area of the North Pacific. Positive (*negative*)

PDO indices correspond with cold (*warm*) anomalies in the central Pacific, with warm (*cold*) anomalies in the Gulf of Alaska and along the coast of North America.

Seasonal and Spatial Variability

Table 1 shows a sample of the 18 stations in Alaska and the ranking (1= warmest, 47=coldest) of 15 El Nino's winter temperatures at each station in relation to the 47 year data set (1957-2004). The indices represent a five month average from Nov-Mar (an expanded version of this table can be found in the appendix). Note when moving across the rows, that some El Nino's are consistently ranked (72/73, 86/87, 02/03), while others are inconsistently ranked (77/78, 87/88). The latter events are an indication of the spatial differences that occur over the large geographic area. Scanning down the columns of Table 1 for a given site indicates the temperature variability from one El Nino to the next. For example, Fairbanks experiences a warm winter during some events and cold during other events. Other locations like St. Paul tend to display some event-to-event variability, but not to the degree that Fairbanks does.

Table 1

year	N3.4	PDO	SOI	pajn	pacv	padq	panc	pakn	pasn	pabe	pafa	paom	paor
02/03	1.2	1.8	-0.9	7	2	2	2	2	4	2	2	2	1
97/98	2.4	1.2	-2.4	4	6	16	9	20	35	21	16	11	6
94/95	1.0	-0.4	-0.6	20	29	37	33	26	38	24	32	35	21
91/92	1.8	0.3	-2.2	2	11	24	19	35	31	39	23	39	15
87/88	0.8	1.3	-0.4	3	9	22	7	19	43	31	7	24	15
86/87	1.3	1.9	-1.6	9	4	3	4	3	6	3	6	3	9
82/83	2.4	0.8	-3.6	15	10	1	15	10	16	10	13	7	26
77/78	0.6	0.3	-1.5	35	25	22	21	10	9	12	27	8	30
76/77	0.7	1.2	-0.1	1	1	6	1	5	24	9	4	9	2
72/73	1.6	-0.3	-0.9	38	41	41	44	46	28	37	25	32	32
69/70	0.7	0.8	-0.6	13	5	12	5	21	27	31	8	26	11
68/69	1.0	-0.9	-0.7	47	45	38	37	39	13	26	46	30	43
65/66	1.3	-0.5	-1.2	43	47	43	43	42	10	36	47	35	45
63/64	0.7	-0.8	-0.5	21	26	25	31	36	38	42	37	44	28
57/58	1.5	0.1	-1.1	14	17	8	15	18	31	15	11	19	12

* N3.4 represents Nino3.4 SST's and are in degrees Celsius. Cooler events are shaded.
A rank of 1=warmest, 47=coolest, ties have the same ranking.

Ironically, it should be noted that <u>the warmest Nino3.4 SST anomalies do not necessarily produce the warmest air temperature anomalies</u>. A good example of this very warm El Nino of 76/77, where the concurrent Nino3.4 index was only moderate (+0.7^{o}C) and the SOI was weak (-0.1). The leading values (Sep.-Dec. average) of these indices were not significantly different from the Nov.-Mar. averages. However, the PDO with a value of +1.2 indicated cooler water in the mid-Pacific, and hence the potential for a deeper than normal Aleutian low. In addition, out that some warm winters appear to be totally unrelated to any El Nino (e.g., note the number of top ten rankings missing from Table 1). Of particular interest is the fact that most El Ninos since the 76/77 event been on the warm side, while previous El Ninos often tended to be cool.

The concurrent <u>seasonal</u> correlation coefficients (Pearson 'r') between Nino3.4 and temperature anomalies for the 18 Alaskan stations range from +0.2 to +0.5, with the largest correlations belonging to maritime sites located along the Gulf of Alaska. If Nino3.4 indices are allowed to lead temperatures by three months- there is only slight increase in the correlation. For comparison, the seasonal (concurrent) correlation between temperature anomalies and the PDO ranges from +0.3 to +0.8, with the majority of stations between +0.6 to +0.7 (moderate correlation). In general the PDO index is better correlated with observed seasonal temperatures than is the Nino3.4 index.

Averaging each row in Table 1 gives an indication of the relative rank of each event. This procedure shows that most, but not all of the ‘cooler’ El Nino’s occurred prior to the event of 76/77. Note that the El Nino’s of 65/66, 68/69, 72/73 had very warm Nino3.4 SST anomalies, yet the resulting air temperatures across most of Alaska were well below normal. Winter temperature data for each station indicates an abrupt ‘jump’ for most sites around the state beginning in 1977. This period corresponds with a shift in the sign of the PDO from negative to positive (referred to in the literature as a ‘regime shift’). Periods of persistent negative PDOs favor 500 mb ridging near the dateline (Bond & Harrison 2000), while positive values favor ridging over the eastern Pacific and western Canada (positive PNA pattern). This tendency for cool El Nino’s to occur in association with negative phases of the PDO, and warm El Nino’s during positive phases of the PDO, suggest that the temperature response of any given El Nino across Alaska is a function of the ‘background’ state of the North Pacific, as indicated by the PDO (Gershunov & Barnett 1998, Niebauer 1998). Prior to 1977 many El Nino’s were concurrent with the negative phase of the PDO. Further more, since 1977 most El Nino’s have occurred concurrent with the positive phase of the PDO.

In order to gain some further insight into the shift that occurred around 1977, the correlation between Nino3.4 and Alaska temperatures during El Nino winters was broken down into two periods: 1957-1976 and 1977-2004. The results indicate that generally east of 145^{o}W correlations have increased in a positive sense from pre-1977 to post-1977. In other words, the correlation between warm SST anomalies in the equatorial eastern Pacific (El Ninos) and warmer air temperatures east of 145^{o}W has increased. In the area roughly bounded by 145^{o}W and 152^{o}W and the Alaska Range south, there has been little change in the correlation coefficients between the two periods. West of 152^{o}W and north of the Alaska Range, correlations in post-1977 have become more negative. That is warm SST anomalies in the equatorial eastern Pacific (El Ninos) typically correspond with either cooler or near normal seasonal temperatures (with occasional warm events).

These results reflect the overall eastward shift in the <u>seasonal</u> 500mb ridge during El Ninos that has occurred in the post-1977 era. An important aspect of this shift is the decrease in <u>the frequency of ridging or blocking events in the mid-Pacific (160^{o}E to 160^{o}W) since 1977</u>. Weak to moderate El Ninos as indicated by the strength of the Nino3.4 index, tend to display considerable short-term variability in the position of the 500mb trough-ridge position throughout the winter (discussed in the next section). Strong El Ninos on the other hand tend to cause this pattern to shift even further eastward. The result is western Alaska is often cooler than normal, while southeast Alaska remains well above normal.

Observations from the Arctic slope as represented by Barrow tend to indicate that the correlation between El Nino’s and warm temperatures is very low. On occasions however, (97/98, 02/03) the impact of an El Nino reaches north of the Brooks Range. This relationship as well as the role of the Arctic Oscillation needs further study.

Monthly Variability

Up to this point in this paper we have only considered the variability in Alaska's air temperatures from one El Nino to the next. However there is of considerable variability during any given event as well. The primary control of winter temperatures in Alaska is the position and amplitude of the 500mb trough-ridge pattern from day-to-day and from week-to-week. Certainly radiative cooling is an important secondary cause, but it is controlled by synoptic scale weather.

Figure 2 shows average monthly 500mb heights at 60^{o}N during the El Nino of 2002-2003. Notice the variability in the amplitude and position of ridge as well as the 'depth' of the Aleutian trough. In general terms, the position of the trough/ridge determines the path of the average monthly storm track (the west side of the ridge). Unfortunately, amplitude is more difficult to summarize. In a climatological sense it is 'normal' for a ridge to form over western Canada (140^{o}W to 120^{o}W stationary planetary wave), thus the amplitude of the observed ridge has to be compared to the amplitude of the climatological ridge. In other words, a higher amplitude ridge would indicate a higher frequency of southerly flow into Alaska (warmer temperatures if all else is equal), while a low amplitude ridge suggests a more zonal (west-east) flow than normal, resulting in cooler than normal temperatures. The observed temperatures around Alaska were for the most part record warmth, with the exception being Mar. which produced either cooler, or near normal temperatures depending on location. Overall, the winter of 02/03 displayed moderate variability when compared to other El Nino's.

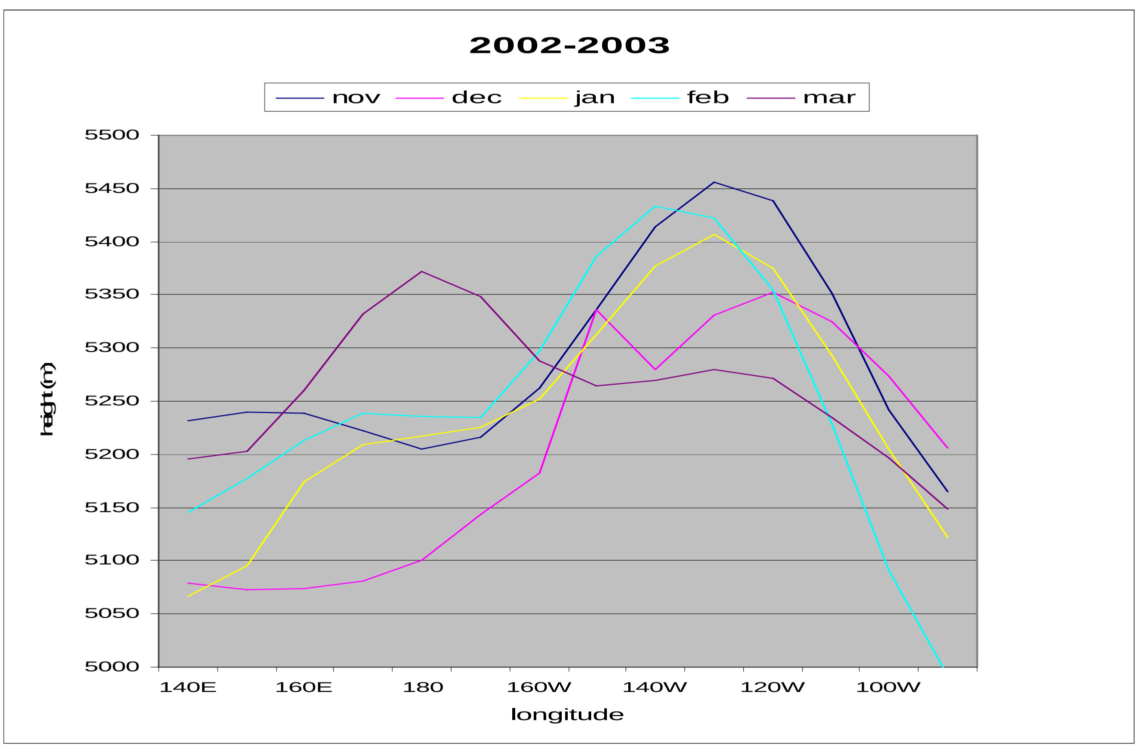

Figure 2: Mean monthly 500mb heights at 60^{o}N for 2002-2003 El Nino.

A shift in the ridge axis of 10^o longitude or more from one month to the next makes a significant impact on temperature anomalies in Alaska. For most of the state the largest El Nino temperature anomalies tend to occur in mid-winter centered on Jan. Note, however, that these same months also have the largest variability. Western Alaska is unique in that the largest temperature anomalies have equal probability of occurring anytime during the Nov. through Mar. period.

Calculating the standard deviations of mean monthly El Nino temperatures prior to 1977 and then comparing to values calculated afterwards, indicates that the variability has decreased since 1977 for virtually all stations with the exception of Cold Bay and St. Paul. The physical interpretation is that there has been over all a decrease in the east-west movement of the storm track (position of 500mb trough/ridge) during the winter months in post-1977 El Nino's. It should be noted that air temperatures have been warming throughout the state for a number of decades, irregardless of the climate zone. However the contribution to that warming from El Nino's varies according to location. Since there has been an eastward shift in the 500mb pattern, we might anticipate that there are significant east-to-west as well as possible north-to-south differences. Analysis of temperature data shows that El Nino's have been the largest contributor to the warming trend in the eastern third of the state including Southeast. In the middle third of the state south of the Brooks Range, El Nino's have had a modest influence on the warming. In western Alaska and the Arctic, El Nino's have had either little or no cooling influence on temperature trends.

'Cool' El Nino's

The El Nino of 1994/1995 produced the coolest air temperatures around the state of any warm event that occurred since1977 (5th coolest of the 15 El Nino's shown in Table 1). Hence it is important to understand why this event differs from the rest. Table 2 shows the relevant indices the summer prior to, and during the winter of this event. By the autumn of 1994 both the Nino3.4 and SOI (MEI as well) were indicating that a substantial El Nino was forming. However, as indicated by the PDO index, there were large areas of the central Pacific that had developed significant warm SST anomalies by Aug/Sep. Recall that a negative PDO index indicates warm SST anomalies in the central North Pacific with cool SST anomalies along the west coast and Gulf of Alaska.

	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Nino3.4	0.7^{o}	0.4^{o}	0.9^{o}	1.4^{o}	1.4^{o}	1.0^{o}	0.8^{o}	0.5^{o}
SOI	-1.8	-1.8	-1.6	-0.7	-1.6	-0.6	-0.5	0.2
PDO	-0.8	-1.4	-1.3	-2.0	-1.8	-0.5	0.5	0.8

Table 2: Indices prior and during the 1994-1995 El Nino. Nino3.4 values are in degrees Celsius.

Warm mid-Pacific SST anomalies peaked in the Nov/Dec period before reversing sign in Feb. The anomalies were very large (+1^{o} to +2^{o} C) and appeared to have controlled the trough/ridge pattern over the North Pacific despite the ongoing El Nino. Throughout that winter this large area of warm water produced a higher frequency of ridges near the dateline (Figure 2) than has been the norm in the post-1977 period. An interesting aspect of this particular event is that Jan. 500mb heights and Alaska temperatures were close to a typical El Nino response. However, the PDO shifted sign in Feb., remaining positive in

Mar. Despite these changes in SST anomalies the 500mb flow in Feb. was nearly zonal while Mar. had a prominent dateline ridge (Figure 2).

An additional contribution to this abnormal El Nino may have been alterations in equatorial convection as evidenced by the Madden Julian Oscillation (MJO). In a normal El Nino winter, enhanced convection occurs near the equator from 170^{o}E to 150^{o}W. This convection strengthens the subtropical jet stream possibly increasing the amplitude of the Canadian ridge as well. During the 94/95 event eastern tropical Pacific convection was weaker than it is during most El Nino's, especially in Feb/Mar, but it was significantly stronger in the western tropical Pacific. This anomalous pattern may be the reason why the polar jet during Feb/Mar was shifted south when compared to normal. As a side note, enhanced convection over the greater Indonesia area in winter is often associated with mid-Pacific ridging (Weickmann *et al* 1985).

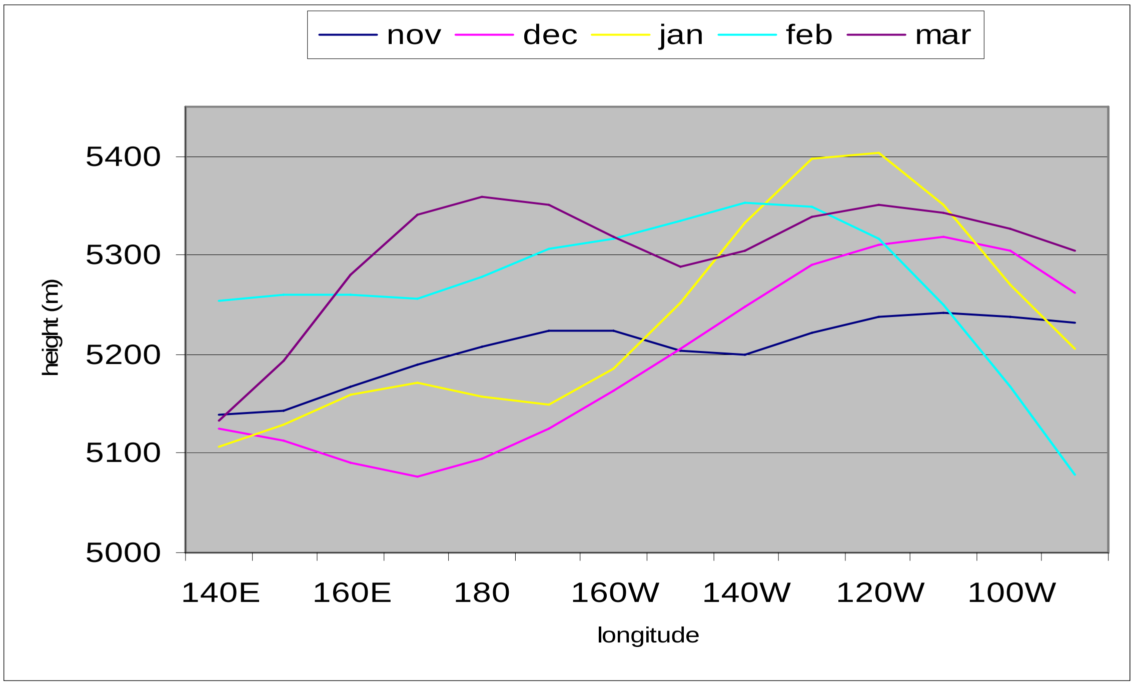

Figure 2: Mean monthly 500 mb heights at 60^{o}N for 1994-1995 El Nino

Discussion

Some recent work suggests that the variation of the PDO is not a separate climate forcing, but rather the North Pacific's lower frequency integration of ENSO forcings (Newman *et al* 2004). In other words, SST anomalies attributed to the PDO are generated by tropical Pacific SST anomalies, although the North Pacific anomalies do not have the same amplitude or frequency as the tropical forcing. The mechanisms by which these processes occur according to the authors appears to be enhanced westerly wind stress (Aleutian low is re-positioned) over the mid-Pacific which in turn causes enhanced oceanic mixing (Deser and Blackmon 1995). In this conceptual model, the re-positioning of the Aleutian low (i.e. *storm track*) during El Nino's is caused by enhanced convection over the central and eastern equatorial Pacific (shift in the Hadley and Walker circulations). An additional consequence of this repositioning of the Aleutian low is that the frequency of northwest winds over the central North Pacific is increased. The transport of cooler air from Siberia and the Bering Sea has a net cooling affect on the ocean, as heat is lost to the atmosphere. In fact cooler near surface air temperatures may actually be the primary forcing agent.

Alexander and Deser (1995) have also suggested that North Pacific wintertime SST anomalies can disappear during the summer months, only to reappear again the next winter. This 'reemergence' theory is based on the observation that SST anomalies are the manifestation of temperature anomalies that occur in the first several hundred feet of the water column. At times it is possible for the surface layer to return to its 'normal' temperature during the summer. Below the surface however, the anomaly remains intact throughout the summer. As wind speeds increase during the following autumn, mixing of surface with sub-surface water re-generates the anomaly at the surface for a second winter.

This paper makes no attempt to argue the case of PDO as a separate climate forcing or as an integrated response to ENSO forcings. Whatever the mechanism, there is a clear SST signal in the North Pacific that has a significant impact on weather in Alaska. However, there is another question that needs answering: Why has there been an eastward shift in ridging in the post-1977 era. It has been suggested that the frequency of El Nino's has increased in the post-1977 period. This of course depends on what index is used and the criteria employed. Using Nino3.4 data, there is a very slight increase in the number of El Nino's and a slight decrease in La Nina's post-1977. The MEI shows more of a distinction in the frequency of events, clearing favoring El Nino's since 1977. Furthermore, no one really understands the implications that rising global temperatures are having on large-scale dynamics. For example, what impact if any is the warming having on the amplitude and position of planetary waves, and the Canadian ridge in particular?

Seasonal Forecasting

As noted earlier observed wintertime 500mb heights over the North Pacific during any given year, including El Nino years, is a function of a number of different 'forcings': tropical Pacific SST's, Madden Julian Oscillations, extratropical Pacific SST's, background state of the flow (climatological), changes in the stratosphere, and internal variability of the atmosphere to name a few.

In a study of 500mb heights, Wang and Fu (2000) found that Nov. and Dec. height anomalies are predominately coupled with North Pacific SST anomalies, while Jan-Mar height anomalies were coupled with <u>both</u> north Pacific and tropical SST anomalies. In other words, their study suggests that the influence of any given El Nino on height anomalies is weak in Nov and Dec but stronger during the Jan-Mar period.

Newman & Sardeshmukh (1998) found that height anomalies over the North Pacific are a function of the monthly averaged 'background state' (the polar jet stream refracts Rossby waves), which varies in both time and space. The strongest signal was obtained for the spring and autumn periods when the polar jet undergoes significant changes in strength and location. The implications of their work: forcings that are <u>steady</u> in time can produce height anomalies that are <u>unsteady</u>. Conversely, <u>unsteady</u> forcings may produce <u>steady</u> height anomalies.

In a study of tropospheric height response to various tropical Pacific SST anomalies simulated by several global circulation models, Hoerling and Kumar (2002) found that the location of the tropical forcing (east, central, west Pacific) does make noticeable different to the height anomalies, especially the position and amplitude of the ridge over western North America. The largest model differences were observed between SST anomalies located in the western versus central Pacific Ocean. The authors point out that these differences are often masked by additional atmospheric variability.

These studies as well as additional research indicate that the observed response in the North Pacific to a given El Nino involves a complex interaction of atmosphere-ocean that generates considerable variability. As a consequence of this variability, long range forecasts tend to be generalized and are primarily based on the predicted ENSO state. As a rule of thumb, variability is higher for short time periods than it is for long periods. Hence, most forecasts are made for a season rather than individual months. The forecaster is relying on the fact that they cannot forecast the details, only the average result.

This paper has demonstrated the importance of North Pacific SST anomalies to winter air temperatures in Alaska. One of the fundamental questions to be addressed is: when an El Nino is forecasted for an upcoming winter, can PDO trends in late summer and autumn be used to make winter temperature forecasts for Alaska? The real question is whether or not the extratropical North Pacific SST's (PDO) are going to reinforce the El Nino pattern (constructive interference) or work against the pattern (destructive interference). We will begin by examining the seasonal timeframe. In order to make a winter forecast, we would need to use data from either the summer or autumn, or from both. Data from the 15 previous warm events indicates that the correlation between observed temperatures and the average Aug.-Sep.-Oct. PDO index for each station in the analysis drops to less than half the correlation when the concurrent (Nov.-Mar.) PDO indices are used.

These low to nonexistent correlations mean, unfortunately, that leading PDO indices cannot used to make a reliable forecast for most sites. The exception is southeast Alaska and the North Gulf Coast where, as a general rule, cool SST anomalies in the central North Pacific in the autumn (positive PDO indices) combined with an El Nino is a fairly reliable indicator of an upcoming warm winter. However, in the Southeast (as with the rest of the state), the magnitude of the warming however is not well correlated with the actual mid-Pacific or equatorial SST anomalies. A forecast nomogram for Southwest might look something like the following-- Probability of warm winter with a forecasted El Nino are:

Aug-Oct PDO >+0.5	*high*
Aug-Oct PDO >-0.5 but <+0.5	*50/50*
Aug-Oct PDO <-0.5	*low*

Besides the magnitude of the three month average, the overall summer/autumn trend of the PDO is important. However, the correlation between autumn and winter PDO values is not very high. Trends switch back and forth, thus factoring in the trend to the PDO scheme adds only a small amount of skill.

Summary

- The impact of any given El Nino on air temperatures in Alaska is a function of the ‘background’ state of the North Pacific. During the positive (*negative*) phase of the PDO, ridging in the mid-Pacific is suppressed (*enhanced*), but is enhanced (*suppressed)* in the eastern Gulf of Alaska and western Canada. Since 1976/1977, 7 out of 9 El Nino’s have generated significant warm temperature anomalies across most of the state. The exception was the 94/95 event and to a lesser extent 91/92.
- The magnitudes of the equatorial and mid-Pacific SST anomalies are poorly correlated with the strength of temperature anomalies in Alaska during the winter months (the same applies to the SOI).
- Since 1976/1977 there has been a fundamental shift in the ‘background’ state of the North Pacific. The amplitude of ridges centered over western Canada has increased while the Aleutian low has shifted about 20^o east. Associated with this shift, the polar jet stream has shifted eastward as well. The net result has been a higher frequency of southerly flow into Alaska with an equally important reduction in the frequency of winter time mid-Pacific ridging (blocks). A fundamental question to be addressed is whether the North Pacific will shift back into a warmer mode, where negative PDO indices dominate?
- There is considerable air temperature variability during an El Nino due to Alaska’s large size. Some El Nino’s produce warm temperature anomalies state wide (*i.e*. 76/77, 02/03) while other events produce more regional anomalies (*i.e*. 77/78, 87/88). There is more variability in temperatures west of 160^{o}W than there is east of this line due to the fact that there is a preference for the ridge axis to form over the eastern Gulf of Alaska and western Canada. In fact, variability east of 160^o W has decreased considerable since 1977, with little or no change in variability west of that line.
- Very strong positive Nino3.4 anomalies shift the Aleutian low and Canadian ridge further east than in weak to moderate El Nino’s. The impact on Alaska temperatures depends on how stable the resulting height anomalies remain. If there is considerable week-to-week variability in the position of the ridge, temperatures may be above normal. However, a stable pattern that remains shifted to the east will tend to produce near normal or cooler temperatures for most locations west of 145^{o}W.
- Use some caution when you attempt or read about composite El Nino analysis for Alaska using pre-1977 events with post-1977 events. It should be obvious at this point why, if not, start from page one and re-read this paper.

Useful Web Pages

Western Region Climate Center: www.wrcc.dri.edu
MEI: www.cdc.noaa.gov/~kew/MEI/table.htm
Climate Prediction Center: (general) www.cpc.noaa.gov
(Indices info) www.cpc.ncep.noaa.gov/data/teledoc
Climate Diagnostic Center: www.cdc.noaa.gov
Alaska Climate Research Center: http://climate.gi.alaska.edu
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Table 3

year	N3.4	PDO	SOI	pant	pajn	paya	pacv	paho	panc	padq	pakn	pacd	pasn
02/03	1.2	1.8	-0.9	1	7	5	2	2	2	2	2	2	4
97/98	2.4	1.2	-2.4	5	4	3	6	14	9	16	20	29	35
94/95	1.0	-0.4	-0.6	21	20	40	29	25	33	37	26	32	38
91/92	1.8	0.3	-2.2	2	2	3	11	18	19	24	35	25	31
87/88	0.8	1.3	-0.4	14	3	12	9	8	7	22	19	36	43
86/87	1.3	1.9	-1.6	10	9	8	4	5	4	3	3	4	6
82/83	2.4	0.8	-3.6	8	15	10	10	6	15	1	10	17	16
77/78	0.6	0.3	-1.5	39	35	31	25	27	21	22	10	21	9
76/77	0.7	1.2	-0.1	7	1	1	1	3	1	6	5	12	24
72/73	1.6	-0.3	-0.9	33	38	34	41	38	44	41	46	34	28
69/70	0.7	0.8	-0.6	6	13	15	5	11	5	12	21	34	27
68/69	1.0	-0.9	-0.7	43	47	42	45	40	37	38	39	9	13
65/66	1.3	-0.5	-1.2	40	43	47	45	42	43	43	42	25	10
63/64	0.7	-0.8	-0.5	24	21	22	26	31	31	25	36	36	38
57/58	1.5	0.1	-1.1	8	14	7	17	12	15	8	18	14	31

year	N3.4	PDO	SOI	pabe	pamc	paom	pafa	pabt	pabr	paor	pagk	**Rank***	year
02/03	1.2	1.8	-0.9	2	2	2	2	1	5	1	2	**1**	02/03
97/98	2.4	1.2	-2.4	21	11	11	16	5	1	6	19	**4**	97/98
94/95	1.0	-0.4	-0.6	24	27	35	32	30	34	21	36	**11**	94/95
91/92	1.8	0.3	-2.2	39	30	39	23	20	34	15	14	**9**	91/92
87/88	0.8	1.3	-0.4	31	13	24	7	6	23	15	6	**7**	87/88
86/87	1.3	1.9	-1.6	3	6	3	6	7	25	9	4	**3**	86/87
82/83	2.4	0.8	-3.6	10	31	7	13	18	29	26	23	**5**	82/83
77/78	0.6	0.3	-1.5	12	13	8	27	17	19	30	32	**10**	77/78
76/77	0.7	1.2	-0.1	9	7	9	4	4	20	2	1	**2**	76/77
72/73	1.6	-0.3	-0.9	37	32	32	25	32	20	32	38	**13**	72/73
69/70	0.7	0.8	-0.6	31	22	26	8	8	36	11	8	**8**	69/70
68/69	1.0	-0.9	-0.7	26	37	30	46	42	27	43	45	**14**	68/69
65/66	1.3	-0.5	-1.2	36	45	35	47	41	32	45	46	**15**	65/66
63/64	0.7	-0.8	-0.5	42	40	44	37	40	47	28	30	**12**	63/64
57/58	1.5	0.1	-1.1	15	11	19	11	14	30	12	17	**6**	57/58

Rank* = overall 15 event ranking, with 1=warmest, 15=coolest