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THE AGONY AND THE ECSTASY OF SOUTHCENTRAL SUMMERS

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Most peoples' expectation of summer is a period of abundant sunshine with warm (relative) temperatures. That idealized picture is often shattered however by the reality of living in the high northern latitudes. The summers of 2010 and 2008 (the agony) for example do not measure up to the Visitors Bureau classic portrait of a sunny inviting vacation spot. All is not forgotten however, the summers of 2003-2005 (the ecstasy) were indeed some of the warmest on record with abundant sunshine and blue skies. Figure 1 shows the average June, July and August (defined as 'summer') air temperatures from Ted Stevens International Airport (PANC), where data exists from 1954 through the present. A couple of points are evident from this graph: First, the majority of warm summers have occurred since 1977. Note that the summer of 2004 was the second warmest while 2008 was tied for the second coldest. Secondly, at times there is considerable variability from one year to the next. The record is not long enough to be definitive; however a casual glance at this graph and it would appear that the variability could be increasing.

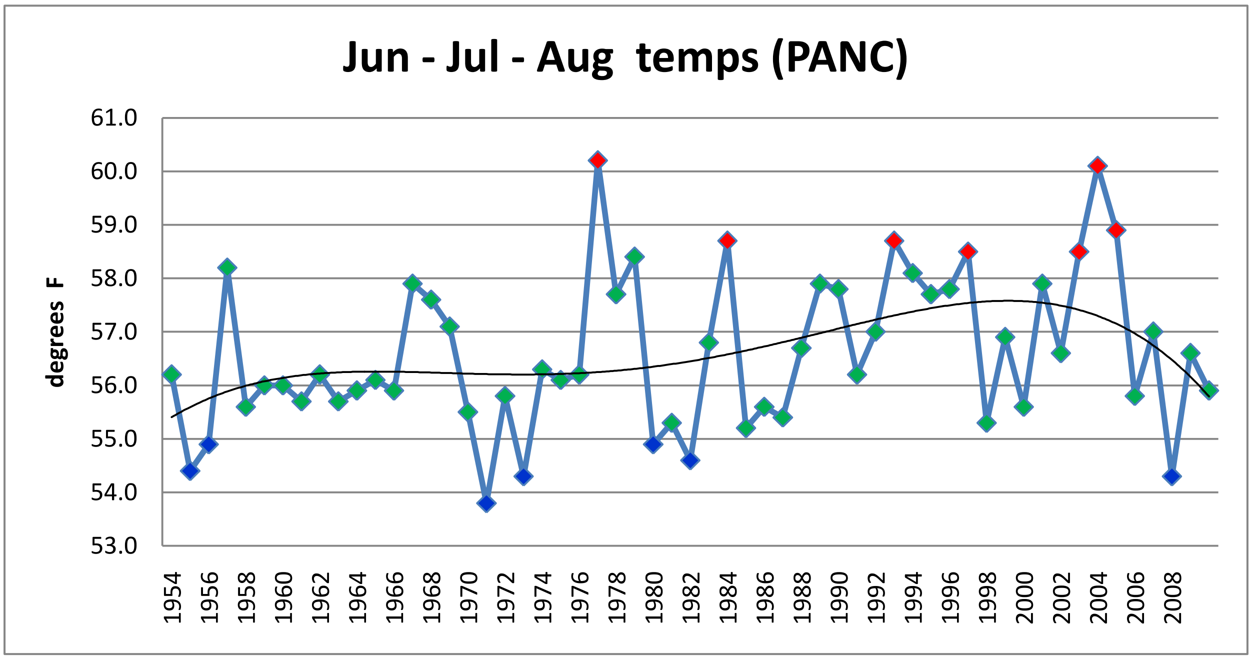


Table 1 displays the seven warmest/coolest summers with the accompanying temperature anomaly (current value minus the long term average) and total rainfall. Note that a warm (cold) summer is only two to three degrees above (below) the long-term average of 56.6^{o} F: a couple of degrees does not seem a very large range, nevertheless these are still significant deviations. Keep in mind that a warm (cold) summer does not of course mean that every day is warmer (cooler) than the long-term average; it does mean that the statistical average is higher (lower). The thin black line in Figure 1 is an attempt at trend analysis- there is certainly an increase in temperatures from 1977 onward but the upward trend has fallen off over the past five summers. The summer of 2010 in comparison tied for 13th coolest (55.9°) with 7.11 inches of rain, well above the normal of 5.46 inches. The only cold month was July which was the seventh coolest during this period.

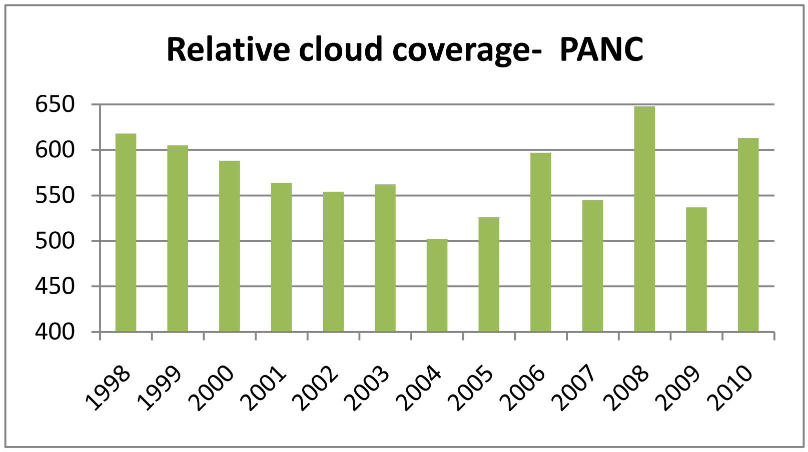
Since Alaska is a very large state with a number of different climatic zones, we have to consider the areal extent of Anchorage temperature anomalies in relation with other regions. A comparison of averaged summer temperatures for Anchorage and Fairbanks indicates that some warm (cold) summers in Anchorage are also warm (cold) in Fairbanks, however the correlation is far from perfect. The summers of 1984 and 2003 were very warm in Anchorage yet the average temperature in Fairbanks for both years was slightly below normal. In contrast, 2004 was very warm in both Fairbanks and Anchorage. In addition, the summer of 1971 which was cold in Anchorage is in contrast with temperatures in Fairbanks that were slightly above normal. For the 1954-2009 period the correlation coefficient between Anchorage and Fairbanks summer averaged temperatures is 0.51, however for the extreme events such as those listed in Table 1, the correlation is on the order of 0.6-0.7 (in other words about 60 -70% of Anchorage extremes will be duplicated in Fairbanks). The less than perfect correlation results from that fact that changes in the weather pattern over one part of the state may or may not impact more distant locales.

Table 1:		WARM		
Rank	Year	Temp (F)	Anomaly	Rain (in)
1	1977	60.2°	+3.6°	3.21
2	2004	60.1	+3.5	2.31
3	2005	58.9	+2.3	5.28
4	1993	58.7	+2.1	4.76
5*	1984	58.7	+2.1	5.42
6	2003	58.5	+1.9	3.91
7*	1997	58.5	+1.9	10.33
		COLD		
RANK	Year	Temp (F)	Anomaly	
1	1971	53.8	-2.8°	5.81
2	1973	54.3	-2.3	5.07
3*	2008	54.3	-2.3	4.80
4	1955	54.4	-2.2	6.16
5	1982	54.6	-2.0	6.30
6	1956	54.9	-1.7	5.19
7*	1980	54.9	-1.7	8.06
* tied rank		1954-2009 average = 56.6° F		

The monthly maximum and minimum temperatures indicate that maximum temperature anomalies for each of the three months are larger than for minimum temperatures. In other words, the departure from normal is larger for maximum temperature (i.e.- daytime highs) than for the corresponding nighttime minimum (low) temperatures. Although not conclusive, this would seem to indicate that cloud cover also is playing some role in temperature patterns.

In general, the presence of clouds during the daytime (summer only) generates cooler temperatures because of the shading affect; cloud cover at night tends to produce warmer temperatures because they trap infrared energy emitted by the earths' surface. [note- clouds during the day light hours in winter tend to make it warmer]. We may infer then that if for any reason the frequency of storms should increase or decrease, the amount of clouds over northern Cook Inlet for example will vary as well. A higher frequency of summer low pressure systems moving through the region would generate more clouds which would, with all else being equal, cool the lower atmosphere during the day and keep it a little warmer at night. If a storm also transports cooler air into the region, the cooler air and shading affect act to reduce daytime temperatures. At night the presence of clouds may offset the cool air or it may just reduce the magnitude of the cooling because the clouds trap infrared energy emitted by the earths' surface. As seen in the monthly temperature data given in the Appendix, the monthly max temperatures show a larger departure from normal than do the minimum temperatures because of the interaction between sunshine and clouds.

One of the drawbacks of living at high latitudes anywhere near the ocean is that summertime high pressure weather patterns produce large areas of low clouds (what we call 'stratus'), due to the very weak downward moving air over the ocean. Hence coastal areas tend to experience significantly longer periods of persistent clouds than areas well inland. Anyone who has lived in the Interior however will know that summer time heating in the morning frequently produces afternoon convection and associated thunderstorms. Convection in many respects acts as a way that the atmosphere redistributes (safety value) surface heating. Summers that are warm tend to produce enhanced afternoon/evening convective clouds which all else equal will tend to reduce the temperatures during the evening hours but potentially increase overnight temperatures if the cloud cover persists. As you can see from this brief sortie into cloud dynamics, the net impact of cloud cover on any given region plays an important role in its' overall climatology.



The last column of Table 1 displays rainfall data; overall cold summers tend to be wetter than warm summers. There is however the occasional exception, for example the summer of 1997 was warm but also very wet. This was the result of a very wet August (two significant convective storms directly over west Anchorage generated localized urban flooding and skewed the data). Higher rainfall totals suggest enhanced cloud cover as well. Figure 2 shows the relative frequency of overcast and broken cloud coverage (half or more of the sky contains clouds) for the 1998-2010 period (since installation of automated sensor). Cold summers (2008, 1998)) have more extensive cloud coverage (stratiform) while warm summers (2004, 2005) often have more localized convective clouds.

With regard to wind events, qualitatively speaking, cold summers and the associated enhanced storminess over northern Cook Inlet generates more frequent strong wind events through gaps in the mountains and over the Western Chugach Mountains. During warm summers when convection is strong, localized strong winds are generated in areas of thunderstorm downdrafts. In addition, abundant clear skies during warm summers also tends to produce stronger afternoon/evening onshore inlet breezes compared to cold summers; this results because the heating over land creates localized areas of lower pressure which in turn allows the higher pressure air over the inlet (which is cooler) to move inland. Hence a strong inlet breeze will tend to reduce temperatures over the land.

One fundamental question that climatologists attempt to answer is whether these summer anomalies are predictable? For example, are there any precursors in the spring that might be an indication of future temperature trends? Inspection of April-May temperatures shows that there is a modest correlation (r=0.60) with Jun-Jul-Aug temperatures for the 1954 to 2009 period. However if we look at the spring temperatures for the summers listed in Table 1, warm summers were preceded by April-May temperature anomaly of +2.2^{o} F, for cold summers the anomaly was -2.3^{o} F. However, there are several outliners to this rule of thumb. The spring of 1977 for example was slightly on the cool side; nevertheless the summer of 1977 was the warmest for the period under consideration. The spring of 1980 was well above normal however the following summer was cool. As with most rules of thumb, there are notable exceptions.

An additional consideration is the relationship between summer temperatures and the various climate indices. Is there any significant connection between sea surface temperatures in the North Pacific (Pacific Decadal Oscillation) or La Nina/El Nino (ENSO) and summer temperatures? Table 2 shows a month-by-month comparison of the linear correlation between temperatures and a number of climate indices (values highlighted in green at statistically signficant. There is modest correlation in June for the PDO and the

Eastern/Northern Pacific pattern (EP/NP), but this correlation is not sustained through July and weakly re-emerges in August for the PDO. The modest June PDO correlation would appear to be a result of what we might label as the lingering winter-to-spring large-scale weather pattern which by July has been terminated. The correlation between the three month average summer temperature and the corresponding three month PDO index is on the order of 0.43. Note that the correlation with the two ENSO indices (SOI, Nino3.4) is nonexistent. If we use the preceding monthly PDO index (for example in the hope of using it as a predictor) and compare it with the next month's temperature, the correlation ranges from a high of 0.47 for June (using May PDO index) to a low of 0.21 for August (July PDO index). In summary, the correlation between average monthly temperatures and the various climate indices is disappointing- it would be difficult to use these separately or in conjunction to form a prediction scheme or find some commonality (what we call 'teleconnections')

Table 2: Correlations

Index	June	July	Aug
PDO	0.55	-.05	0.34
SOI	-.17	-.13	-.39
Nino3.4	.13	.27	.26
AO	.10	.20	-.11
EP/NP	.55	.10	.03
PNA	-.08	.04	.30
NP	-.10	-.01	-.50

Large-scale Weather Patterns:

So far we have only considered the characteristics of warm and cold summers without mention of why they occur. The first step is to examine the large-scale weather patterns and see what the difference is between a cold summer and a warm summer or between a cold (warm) summer and the long-term average (what we might consider as 'normal'). The predominate weather feature during the summer months over the greater Alaska region (dateline to western Canada and the pole to central North Pacific) is an area of lower pressure (trough) over the Bering Sea. This is similar to the winter pattern except it is not as intense and does not extend as far south, in other words this is a weaker summer version of the Aleutian Low. This trough extends from the surface well into the stratosphere (+20 miles) and is strongest in June. The axis or center of the trough tends to be aligned near the dateline. In addition, an area of lower pressure also extends from the Eastern Bering Sea into the western Gulf of Alaska. Further to the east a ridge of high pressure is commonly found over the mountains of western Canada, this ridge is stronger near the ground and weakens with height.

If we examine cold summer months (see Appendix) the most common change in the weather pattern is an eastward and sometimes a southward shift in the trough into western Alaska. In association with the shift in the trough, the ridge over western Canada is weaker than normal. The net result is transport of cooler air from the southern Bering Sea into Southcentral Alaska by southwesterly flow (the air moves from southwest to northeast). Sometimes these changes in the weather patterns are dramatic and other times they are quite subtle. Warm summer months display two predominate types of weather patterns. First, the area of lower pressure over the western Gulf of Alaska is enhanced; this is often associated with a stronger ridge over western Canada. The net result is southeast flow (the air moves from southeast to northwest) from the eastern Gulf of Alaska into Southcentral Alaska. Often the Bering Sea trough is shifted to the west as well. The second common warm pattern is what we might call a 'super trough-ridge' pattern. In this case the axis of the Bering trough remains near the dateline but it extends further south in conjunction with an amplified ridge over western Canada; the net result is south flow (the air is moving from south to north) into Southcentral bringing relatively warmer Pacific air in contrast to cooler Bering Sea air. The aforementioned weather patterns are not exclusive; other patterns can occur but are not as common.

This is a good point to remind the reader that we have been focusing on Anchorage temperature data to define warm and cold summers, which in turn is fairly representative of Southcentral Alaska. However depending on how the large-scale weather pattern forms, areas outside Cook Inlet may or may not have the same temperature anomaly. In other words, some summer temperature anomalies are nearly statewide while others are fairly localized.

The next step is to try and figure out what controls these various summer weather patterns. This of course is the elusive prize for climatologists, because if we know the cause(s) then we should have fairly good success at predicting the effect. To make a long story short, we know what the effects are, but we are not sure what the cause(s) are. Most likely there are a number of different perturbations in the larger-scale flow that can produce anomalous weather patterns. For example researchers have noted that changes in stratospheric temperatures can impact weather patterns near the ground. Other possibilities are temperature and flow anomalies over Asia which in turn migrate downstream over the North Pacific. Sea surface temperatures in the north Pacific play some role as well, but how large of a role remains to be determined.

Referring back to Figure 1, it was noted that the warmest seven summers have occurred since 1977 with five (or six) of the coldest seven summers were prior to 1977. This suggests that something important within the climate system occurred on or near 1977. Over the past several decades climatologist and other researchers have noted various shifts in the climate and other environmental parameters in the North Pacific region; a significant shift occurred in 1977. What has produced this shift is not known at the present time although it would appear that the climate system is controlled by various internal and external sources which tend to interact in various degrees at various times- the net result is a climate that shows considerable variability.

Summary:

Here is a summary of what we have been discussing. Take note that there are notable exceptions to these broad conclusions.

Cold Summers

1) Cooler air is transported from the arctic through the Bering Sea region into Southcentral often via southwest-south flow in the lowest layers of the atmosphere.
2) More active storm track in the Gulf of Alaska- enhanced clouds and rain move onshore.
3) Enhanced number of regional wind events.

Warm Summers

1) Enhanced high pressure and ridging over western Canada which often extends to the Arctic Slope.
2) Drier with fewer clouds- however high frequency of convective storms.
3) Reduced regional wind events but stronger local inlet breezes.

Appendix:

These tables list the top seven (more in cases of tie of the monthly average) warmest and coldest summer months as well as precipitation; based on the 1954-2010 period at PANC. Temperatures are in degrees Fahrenheit with precipitation in inches. Abbreviations used are as follows:

Ave = represents the average of the seven (or more) values given in the table.

Period = represents the 1954-2010 average value.

Diff = is the difference between the 1954-2010 average and the average of the seven (or more) extreme events.

June: Warm				
Year	Max T.	Min T.	AVE	Precip
1984	66.3	51.3	58.8	1.10”
2001	66.4	49.8	58.1	0.33”
1957	66.8	49.2	58.0	0.56”
1977	65.7	49.9	57.8	0.49”
1969	65.1	50.2	57.7	0.18”
2004	65.7	49.2	57.5	0.86”
1990	64.4	49.7	57.1	1.52”
Ave:	65.8	49.9	57.9	0.72”
Period	62.4	47.3	54.8	1.03”
Diff:	+3.4°	+2.6°	+3.1°	-0.31”

June: Cold				
Year	Max T.	Min T.	AVE	Precip
1971	58.3	44.0	51.2	0.37”
1955	58.3	44.0	51.2	1.18”
1973	58.4	44.4	51.4	1.07”
2008	57.6	45.6	51.6	0.63”
1963	58.3	44.8	51.6	1.82”
1972	58.2	45.6	51.9	0.61”
1985	59.0	44.7	51.9	1.01”
1987	58.0	45.7	51.9	1.09”
Ave:	58.3	44.9	51.6	0.97”
Period	62.4	47.3	54.8	1.03”
Diff:	-4.1°	-2.4°	-3.2°	-0.06”

July: Warm				
Year	Max T.	Min T.	AVE	Precip
1977	70.4	54.7	62.6	1.37”
2003	69.4	55.1	62.3	1.26”
2004	69.2	54.5	61.9	0.69”
2005	67.9	54.8	61.4	1.03”
1993	68.9	53.3	61.1	0.57”
1984	66.6	54.9	60.8	1.11”
1997	67.6	54.0	60.8	1.36”
Ave:	68.6	54.5	61.6	1.06”
Period	65.3	51.6	58.5	1.85
Diff:	+3.3°	+2.9°	+3.1°	-0.79”

July: Cold				
Year	Max T.	Min T.	AVE	Precip
1971	61.8	49.0	55.4	2.86”
1959	61.7	49.6	55.7	4.43”
2008	61.3	50.3	55.8	3.25”
1982	62.6	49.8	56.2	2.41”
1956	63.6	49.0	56.3	3.07”
1958	63.2	49.5	56.4	4.44”
2010	61.8	51.3	56.6	3.02”
Ave:	62.3	49.8	56.1	3.35”
Period	65.3	51.6	58.5	1.85
Diff:	-3.0°	-1.8°	-2.4°	+1.50”

August: Warm				
Year	Max T.	Min T.	AVE	Precip
2004	70.4	52.0	61.2	0.76”
1977	67.1	53.4	60.3	1.35”
1978	68.6	51.0	59.8	0.54”
1989	65.0	52.9	59.0	9.77”
1979	65.4	52.1	58.8	1.56”
1993	65.2	52.4	58.8	4.02”
1994	66.1	51.4	58.8	1.02”
Ave:	66.8	52.2	59.5	2.72”
Period	63.3	49.6	56.5	2.63”
Diff:	+3.5°	+2.6°	+3.0°	+0.09”

August: Cold				
Year	Max T.	Min T.	AVE	Precip
1998	59.8	47.7	53.8	3.25”
1973	59.6	47.9	53.8	3.40”
1969	62.2	46.2	54.2	0.33”
1986	60.0	48.6	54.3	3.62”
1966	59.6	49.2	54.4	2.47”
1980	61.1	47.7	54.4	3.06”
1955	61.9	46.9	54.4	3.26”
Ave:	60.6	47.7	54.2	2.77”
Period	63.3	49.6	56.5	2.63”
Diff:	-2.7°	-1.9°	-2.3°	+0.14”