



National Park Service – Rocky Mountain Network

Inventory and Monitoring Program

**Rocky Mountain National Park**  
**Weather and Climate Summary Report for 2006**  
***-Prototype-***

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# 1. Introduction

This report provides a summary and analysis of weather and climate within and around Rocky Mountain National Park (ROMO) for 2006. It presents summaries six different datasets that represent different space and time scales of process –weather stations within and around the parks, park-level indices, SNODAS, PRISM, Climate Divisions, and atmospheric indices.

This 2006 report has the following goals:

- Provide a general summary of ROMO's climate for 2006 by describing climate parameters that are relevant to ecological processes and management decisions – temperature, precipitation, snow cover, and drought;
- Quantify the strength of the climatic relationships at different spatial and temporal scales;
- Provide an inventory of the available datasets related to climate that are available for further analysis;
- Provide a working example of a climate report to determine what analyses and graphics are most useful for management decisions and guide discussions for future content;

This report is not intended to provide a comprehensive analysis of climate, provide a full physical understanding of why changes occur, or determine long-term trends in climate. Based on the findings of the annual reports, the Network plans to provide a more detailed trend analysis once every 5-7 years which will investigate these trends and relationships in more detail.

This report is organized into the following sections:

- Section 2 briefly describes the data and methods. A full description of these methods will be described in the ROMN Weather and Climate Protocol [TBD].
- Section 3 provides an analysis and summary of the individual datasets.
- Section 4 integrates and summarizes the various datasets with a discussion of the key climate variables including temperature, precipitation, drought and snow.

## 2. Data and Methods

This section briefly outlines the data and methods used for this protocol. Full descriptions of the data and methods will be described in the Protocol [TBD].

### ***2.1. Weather and Climate Stations***

In 2006, ROMN collected long-term data for a total of 49 active weather and climate stations within 40 kilometers of ROMO (Figure 1); 13 of the stations are within the park.

These stations were identified by the NPS Climate Inventory (Western Regional climate Center, 2007) as being relevant to the park. Although many of the stations fall outside of the park boundary, because climate is generally more homogenous over longer temporal and larger spatial scales, these stations still may contribute to understanding ROMO's climate.

Station-level data was collected from three monitoring networks:

- National Weather Service Daily Coop Stations (COOP; National Weather Service Cooperative Network 2007) - The COOP network has been a foundation of the U.S. climate program for decades. Manual measurements are made by volunteers and consist of daily maximum and minimum temperatures, observation-time temperature, daily precipitation, daily snowfall, and snow depth.
- Snowpack Telemetry (SNOTEL; Natural Resources Conservation Service 2007) - The USDA/NRCS maintains a network of automated snow-monitoring stations implemented to measure daily precipitation and snow water content. Many modern SNOTEL sites now record hourly data, with some sites now recording temperature and snow depth. Most data records began during or after the mid-1970s.
- SnowCourse (NRCS-SC, National Operational Hydrologic Remote Sensing Center 2004) - These are all manual sites, measuring only snow depth and snow water content one–two times per month during the months of January to June. Data records for these sites often extend back to the 1920s or 1930s, and the data are generally of high quality.

Table 1 (Appendix A) further summarizes the stations for each network and indicates the period of record and their current status.

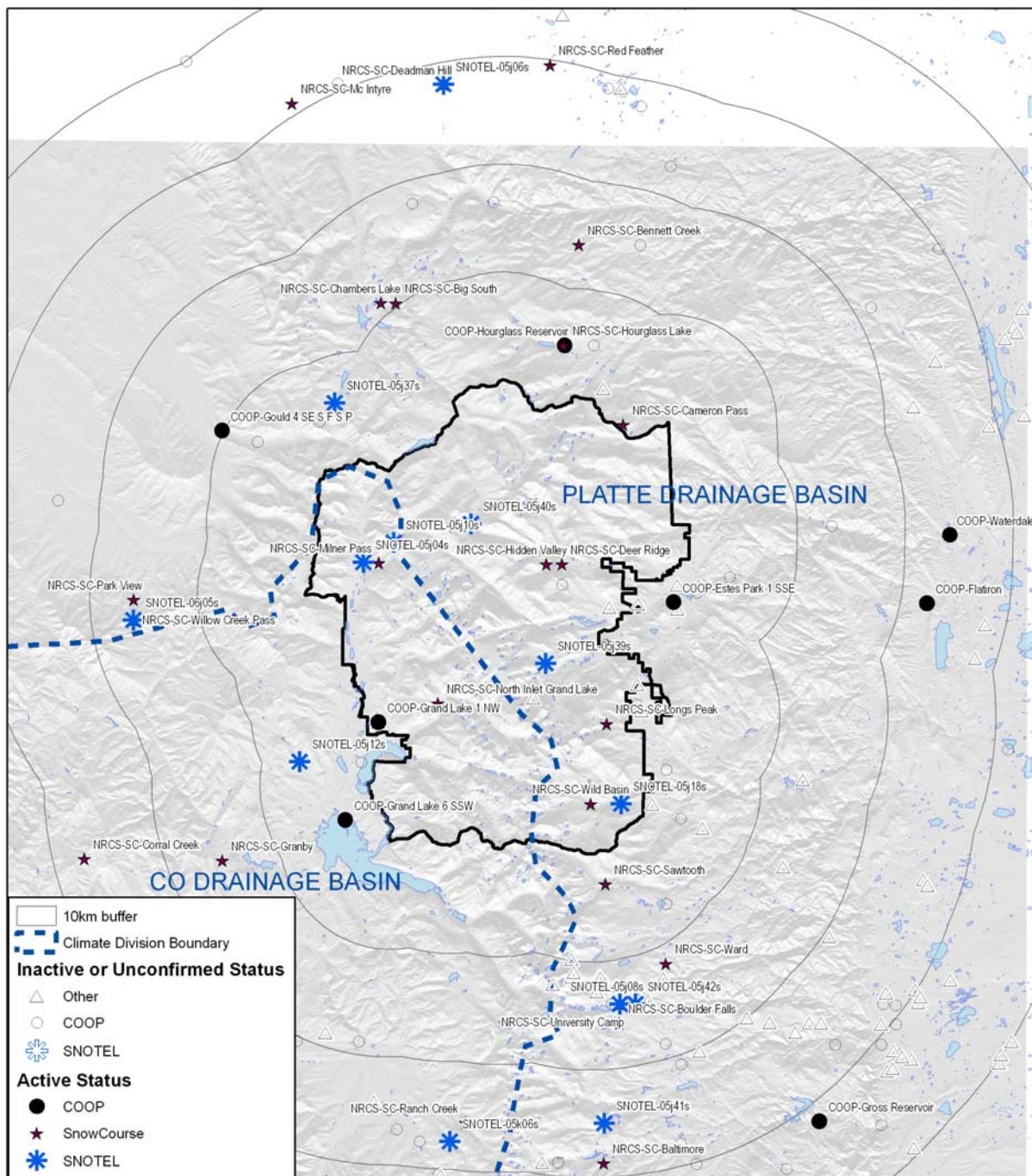


**Figure 2.1. Locations of Weather and Climate Stations Within and Around ROMO**

For stations active in 2006, there are a total of 15 stations on the western side and 34 on the eastern side of ROMO. A complete and detailed analysis (e.g., evaluation of temperature, precipitation and/or Snow Water Equivalent (SWE) of each station) is beyond the scope of this report. Therefore, Tables A.1, A.2, A.3 and A.4 summarize temperature, number of frost free days, heating and cooling degree days, and

precipitation for all stations with daily observations (i.e., COOP and SNOTEL sites). The last three months of SNOTEL sites are not shown because they will not be available until after the completion of this report.

Of the confirmed active weather stations within the park, one (COOP-Grand Lake 1 NW) is located on the western side of ROMO. Although the east side does not have a confirmed active station, COOP-Estes Park 1 SSE is within 2-km of the park entrance. These two stations, when appropriate, are treated as the official point-based observations representative of the east and west sides of the park.

Station observations provide valuable information on the conditions specific to their location. Foremost, station-level observations can extend back to the late 18<sup>th</sup> century, thereby providing a dataset for understand recent changes and trends. Furthermore, because they are not modeled from any other dataset, they are the foundation of all other climate datasets

However, the strengths of the station-level observations can also become their weaknesses. Care should be taken when generalizing beyond that point, especially when considering discontinuous variables such as precipitation. When attempting to generalize to a park-level scale, point-based observations are difficult to work with for the following reasons:

- Micro-scale climate - e.g., difference resulting from proximity to parking lots, walls, water, trees, vents, etc. that may affect representative measurements;
- Meso-scale climate – Relationship to individual storm events. This is especially problematic in summer when convective rainfall will unevenly distribute rain.
- Data Errors – Errors related to the instrumentation or recording of the information
- Shortness and discontinuity of records – Some stations do not have 30 years worth of observation and/or have substantial data gaps.

One approach that addresses these shortcomings is the development of a daily park-level index. This index utilizes all available observations for a particular day and can account for changes in elevation as well the proximity of the station to the park. Individual indices can be developed for particular park regions, e.g., the eastern and western sides of ROMO, to account for physical factors which may cause climate to vary independently.

Daily average temperature (TMEAN) and precipitation (PPT) indices were calculated for the eastern and western slope of ROMO using all available observations (see Table A.1). All of the NWS coop data was utilized for all stations within 40km of the park boundary and includes stations that are no longer active. Evaluation of the SNOTEL

data revealed considerable errors, especially with summertime maximum temperatures. Therefore, without further quality control, SNOTEL temperature and precipitation were quarantined and not used to generate the index for this report.

The daily TMEAN and PPT indices required consideration of elevation and distance to the park. Because temperature is influenced by elevation, a station's daily temperature was adjusted by the empirically-defined environmental lapse rate (~3 degrees Fahrenheit per 1000 meters;  $R^2 = 0.71$ ) and calibrated to the COOP-Estes Park 1 SSE station for the east and COOP-Grand Lake 1 NW station for the west. An empirical evaluation of precipitation found that it increased at an average rate of 0.00003 inches (east side;  $R^2 = 0.58$ ) and 0.00007 inches (west side;  $R^2 = 0.89$ ) per meter. Similar to temperature, precipitation was calibrated to the west and east side stations. Finally, all stations were weighted according to their distance to the park using a 1/distance function (Equation 1).

$$C_{day} = \sum \frac{S_{day} E}{D}$$

Equation 1. Weighting of individual stations to develop daily park-level index [in development].

Where  $C_{day}$  is the climate variable observed for a particular day (TMEAN, PPT, etc)

$S_{day}$  is the station-level observation for the climate parameter on that day;

Because SNOTEL weather observations are not included in the calculation of the daily TMEAN and PPT indices, it is possible that the index does not account for important variations at higher elevations within ROMO.

SWE was calculated monthly using the average SWE observed anytime within the first 25 days of the month. SWE increased by 0.0163 inches per meter ( $R^2 = 0.45$ ) and was calibrated to the SNOTEL-05j18s (east side) and SNOTEL-05j04s (west side) elevations. The later days of the month (days 26-31) were associated with the next month to complement the SnowCourse sampling strategy. Similar to TMEAN and PPT, distance to the park boundary affected the weight and any observation to the index.

In summary, the calculated daily indices (not shown) include TMEAN, PPT and SWE. For each index, the number of reporting stations as well as the number of stations reporting from within the park boundaries is also included. PPT and TMEAN extend

back to the first observations in 1893; SWE extends back to 1936 (East) and 1938 (West), respectively.

Although a park-level index is a powerful indicator of climate conditions within ROMO, it:

- Is never representative of any single point within the park; and
- May be removing important climate signals relevant to certain ecological processes.

## **2.2. SNODAS**

The Snow Data Assimilation System (SNODAS; National Hydrologic Remote Sensing Center 2004) integrates surface-based and remotely sensed observations to create a daily 1-km gridded dataset that includes Snow Depth, Snow Water Equivalent (SWE), and Snow Extent. This data is available since 2003. The first day of each month was collected for the year 2006 snow season (October 2005-July 2006).

## **2.3. PRISM**

Parameter-elevation Regressions on Independent Slopes Model (PRISM; Oregon State University, 2007) data is produced monthly and extends back to 1895. It is offered at numerous spatial scales with the 800-m grid being both free and of reasonably high resolution. PRISM's greatest utility is that it presents the spatial distribution of temperature and precipitation which single point observations and the park index are unable to provide. Monthly PRISM grids for the 2006 season along with the 30-year normals (1971-2000) were collected and processed into a format readable in ArcGIS.

## **2.4. Climate Divisions**

NOAA (National Oceanic and Atmospheric Administration, 2007) produces monthly climate division indices for temperature, precipitation and a number of important drought indices that are key to integrating a number of climate elements including temperature, precipitation, wind and soil conditions:

- Palmer Drought Severity Index (PDSI) - a meteorological drought index used to assess the severity of dry or wet spells of weather;
- Palmer Z Index (ZNDX) - responds to a month of above-normal precipitation, even during periods of drought
- Modified Palmer Drought Severity Index (PMDI) - calculates three intermediate parallel index values each month, but only selects one on the basis of probabilities.
- Palmer Hydrological Drought Index (PHDI) - used to indicate the severity of a wet or dry spell and assess the long-term moisture supply. This index is based on the principles of a balance between moisture supply and demand.

ROMO straddles two climate divisions which represent different climate zones – the Colorado Drainage Basin (Division #2) on the west slope and the Platte Drainage Basin (Division #4) on the east slope (Figure 2.2).

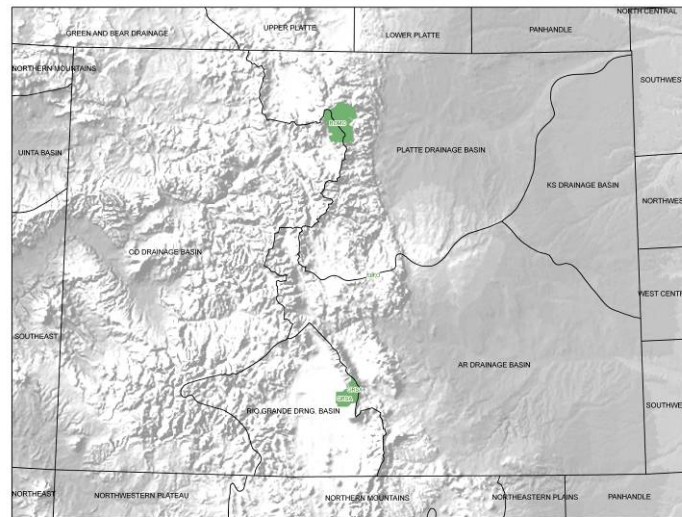


**Figure 2.2. Climate Divisions of Colorado**

In addition to the national climate division data, Colorado also produces its own surface Water Supply Index (SWSI; CDWR 2007). This index is designed to complement the PDSI in the state of Colorado, where mountain snowpack is a key element of water supply. It is based on stream flow, reservoir storage, and precipitation for the summer period (May through October).

The following data, Table 2.1, were collected for the relative divisions and state indices:

| Division            | Name                                                                     | Network Description                          | Year Begin | Year End |
|---------------------|--------------------------------------------------------------------------|----------------------------------------------|------------|----------|
| NCD-5-2             | Colorado Climate Division 2: Colorado Drainage Basin (West Side of ROMO) | NOAA Climate Divisions                       | 1895       | 2006     |
| NCD-5-4             | Colorado Climate Division 4: Platte Drainage Basin (East Side of ROMO)   | NOAA Climate Divisions                       | 1895       | 2006     |
| COSWSI-Colorado     | Colorado Basin                                                           | State of Colorado Surface Water Supply Index | 2005       | 2006     |
| COSWSI-South Platte | South Platte Basin                                                       | State of Colorado Surface Water Supply Index | 2005       | 2006     |

**Table 2.1. Current Inventory of Climate Division Data**

## **2.5. Atmosphere & Ocean Indices**

Long-term and large-scale atmospheric and ocean variations play a key role in understanding and predicting intra-seasonal and inter-annual variations in climate (Climate Diagnostics Center, 2007b). Some of the key variations relevant to ROMO

include the North Atlantic Oscillation (NAO; Wang et al. 2002), Pacific Decadal Oscillation (PDO; Gray et al 2003; Westerling and Swetnam 2003), Pacific-North American pattern (PNA; Barnston and Livezey 1987), El Nino Southern Oscillation ENSO (described using the Southern Oscillation Index- SOI; Gray 2003; Schoennagel et al. 2005) and the Atlantic Multi-decadal Oscillation (AMO; Gray et al. 2003). Table 2.3 summarizes the periods of record collected for each index.

| Atmosphere / Ocean Index | Name                               | Year Begin | Year End |
|--------------------------|------------------------------------|------------|----------|
| CPC-NAO                  | North Atlantic Oscillation         | 1950       | 2006     |
| CPC-PDO                  | Pacific Multi-decadal Oscillation  | 1900       | 2006     |
| CPC-PNA                  | Pacific North American Pattern     | 1950       | 2006     |
| CPC-SOI                  | Southern Oscillation Index         | 1882       | 2006     |
| CPC-AMO                  | Atlantic Multi-decadal Oscillation | 1950       | 2006     |

**Table 2.2. Inventory of Atmospheric and Oceanic Indices**

Table 2.3 presents a very limited summary of first order impacts to climate. These were derived from a simple climate division-atmospheric correlation using the CDC Climate Division/atmospheric index correlation tool (Climate Diagnostics Center, 2007a).

| Atmosphere / Ocean Index | Positive Phase Climate Impacts                         | Negative Phase Climate Impacts                         |
|--------------------------|--------------------------------------------------------|--------------------------------------------------------|
| CPC-PDO                  | +Precipitation<br>-Temperature (east side)<br>-Drought | -Precipitation<br>+Temperature (east side)<br>+Drought |
| CPC-PNA                  | +Precipitation<br>-Drought                             | -Precipitation<br>+Drought                             |
| CPC-SOI                  | +Precipitation<br>+Drought                             | -Precipitation<br>-Drought                             |
| CPC-AMO                  | +Temperatures (west side)<br>+Precipitation            | -Temperatures (west side)<br>-Precipitation            |

**Table 2.3. First-Order Effects of Atmospheric and Oceanic Indices on ROMO's Annual Climate.**

First order effects are defined as those occurring in the same year and relating directly to primary climate variables, including precipitation, temperature and drought. As such, this analysis is extremely limited because it considers only average annual effects and ignores many of the identified seasonal relationships. In the future, there are a number of other relationships which should also be considered:

- Intra-seasonal;

- Time lags between the index and ROMO's climate;
- Indirect effects to ecological processes;
- Interactions among indices that may attenuate or enhance climatic and/or ecological effects.

### **3. Results and Discussion**

This section focuses on the climate parameters key to the management of ROMO's natural resources and the ROMN protocols – temperature, precipitation, snow, and drought. Research has demonstrated that each of these parameters is controlled by larger-scale variations of the ocean and atmosphere. Therefore, this section will also investigate how these variations are related to ROMO's surface environment.

#### ***3.1. Temperature***

Within the park temperatures ranged from 92 to -13 F along the east side and 89 and -23 F along the west (Table A.2). The growing season, as defined by the last and first frosts, ranged from May 16 to September 2 (109 days) on the east side and June 26 to August 28 (63 days) along the west (Table A.3).

Figure 3.1 shows the monthly departure of ROMO's temperature from the long-term mean for both sides of the park using the derived park index (see section 2.1).

Temperature departures were similar for both sides of the park with higher than normal temperatures during the summer and winter months and below average temperatures during spring and fall. A correlation analysis between both sides shows they were highly correlated ( $r = 0.91$ ) in 2006.

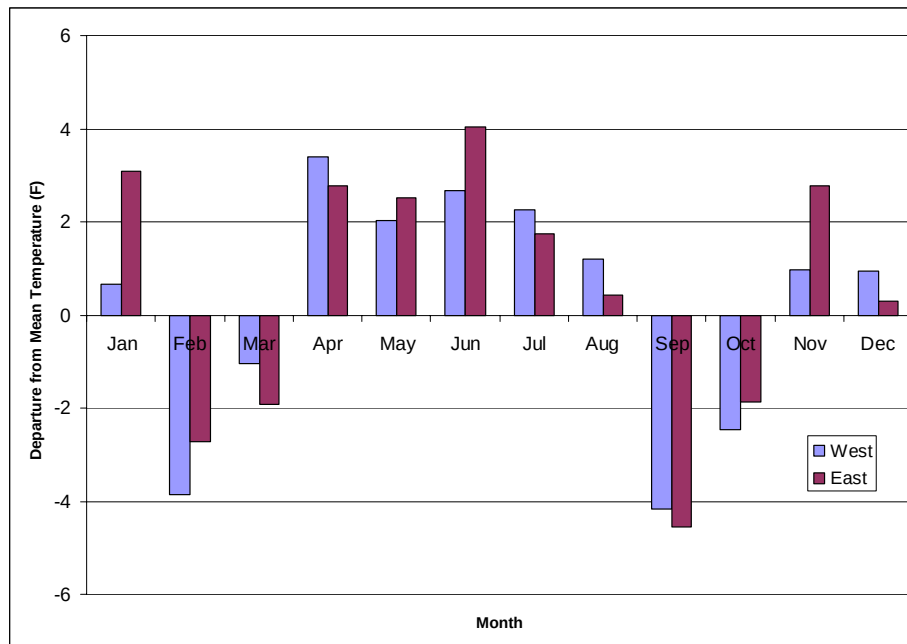


**Figure 3.1. Monthly Temperature Departures from the 30-year mean for the West and East Sides of ROMO, 2006. Derived using the park-level index.**

Monthly temperature anomalies using the Climate Division Dataset (Figure 3.2) is almost identical to Figure 3.1. Monthly correlations between each side were 0.91 (west side) and 0.96 (east side). These relatively high correlation coefficients suggests that ROMO's monthly variations were comparable to what occurred regionally, at least for 2006.

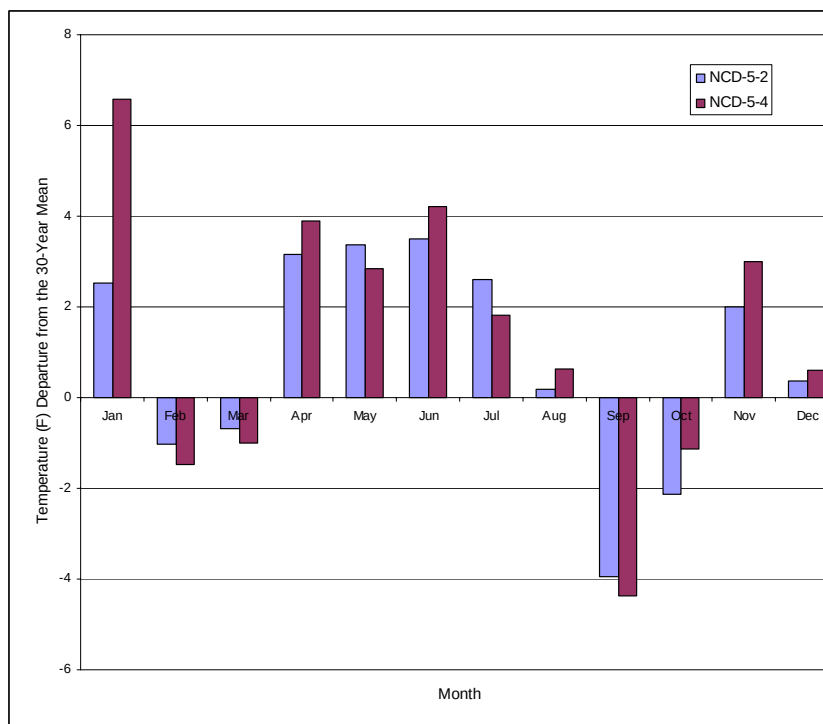


**Figure 3.2. Monthly Temperature Anomalies for Colorado Climate Divisions 2 (West) and 4 (East), 2006.**

Although ROMO's aggregated temperatures followed regional variations, there were still some spatial variations within the park. Figure 3.3 shows that the higher elevations and the northeastern portion of the park were slightly below average in temperature for the year. Overall, approximately 63% of the park experienced above-average temperatures for the entire year.

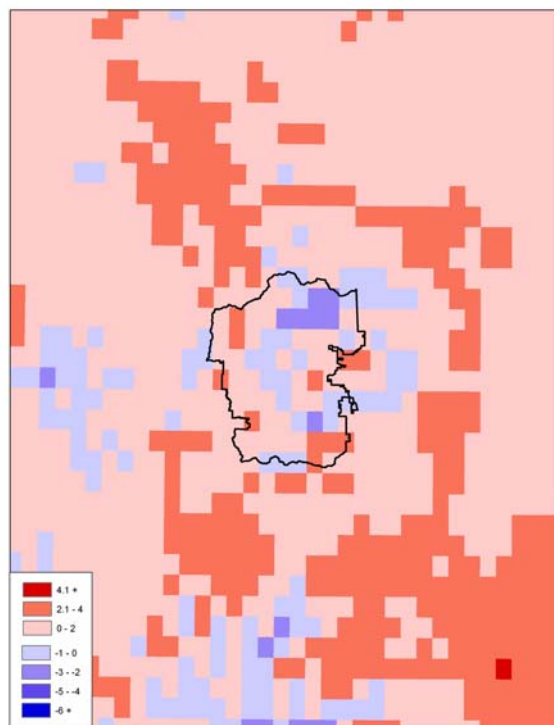


**Figure 3.3. Departure from the Mean (1970-2000) of Average Annual Mean Temperature for 2006. Units are degrees Fahrenheit. Data is derived from PRISM.**

Figure 3.4 provides a longer-term perspective of how ROMO's average temperature has varied over the last 30 years. Since 1994, temperatures have been almost consecutively above normal along the west side; the east side has generally experienced above normal temperatures since 1998. Variations between the east and west side at the annual time scales are significantly weaker than they were for the 2006 monthly anomalies ( $r=0.42$ ).

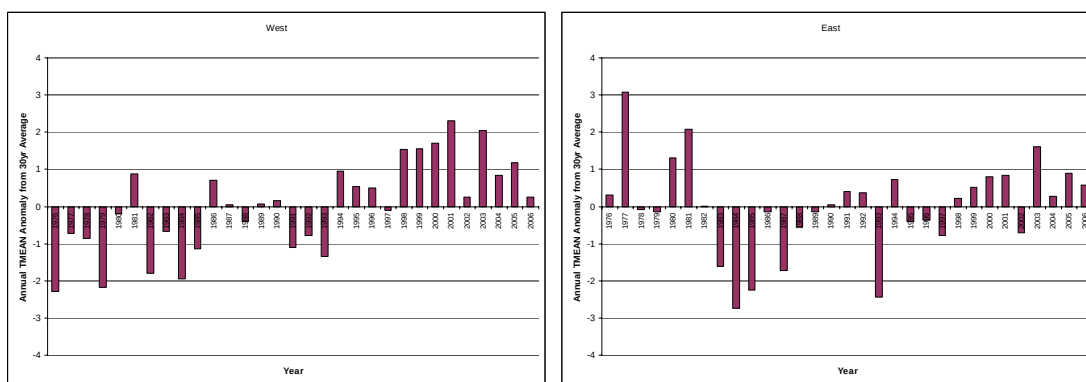


**Figure 3.4. Annual Average Temperature Departures from the 30-Year Mean for the West and East Sides of ROMO, 1976-2006. Departures created using the park-level index.**

Figure 3.5 presents these same temperature variations for the larger climate division regions. Both regions exhibited similar inter-annual variations ( $r=0.90$ ). A comparison of park-level and regional indices indicates that the west side of ROMO followed the regional trends ( $r=0.91$ ), but that the east side of ROMO was not as closely correlated to the eastern climate division temperature indices ( $r=0.76$ ).

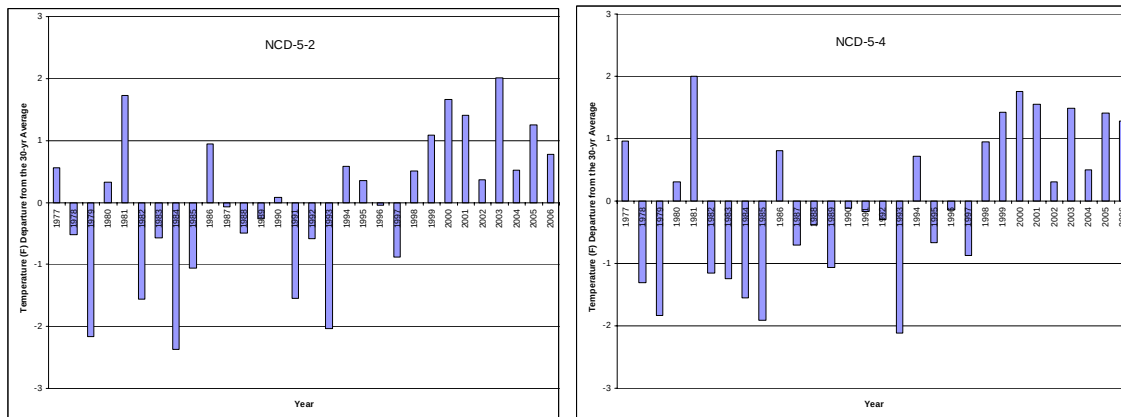


**Figure 3.5. Average Annual Temperature Departures for Colorado Climate Divisions 2 (West Side of ROMO) and 4 (East Side of ROMO), 1977-2006.**

Table 3.1 lists the 30-year correlation coefficients between the west and east sides of ROMO and the major atmospheric and oceanic indices. Annual temperatures appear to be closely associated with the AMO (Figure B.1) along the west side and the PDO (Figure B.2) along the east.

| <i>Index</i> | <i>West Side</i> | <i>East Side</i> |
|--------------|------------------|------------------|
| CPC-AMO      | <b>0.71</b>      | 0.23             |
| CPC-TNH      | -0.31            | -0.07            |
| CPC-SOI      | 0.26             | 0.08             |
| CPC-PNA      | 0.04             | 0.00             |
| CPC-PDO      | -0.23            | <b>-0.42</b>     |
| CPC-NAO      | -0.20            | -0.18            |

**Table 3.1. 30-yr Annual Correlations Between the Atmospheric/Oceanic Indices and Eastern and Western Slope Annual Temperatures of ROMO. Highest correlations are bolded.**

### 3.2. Precipitation

Figure 3.6 presents the monthly precipitation departures for the west and east sides of ROMO using the park-level index. Both sides experienced lower than normal

precipitation totals from January through June, with notable elevated departures in July. Monthly precipitation variations were comparable on both sides of the divide ( $r = 0.88$ ).

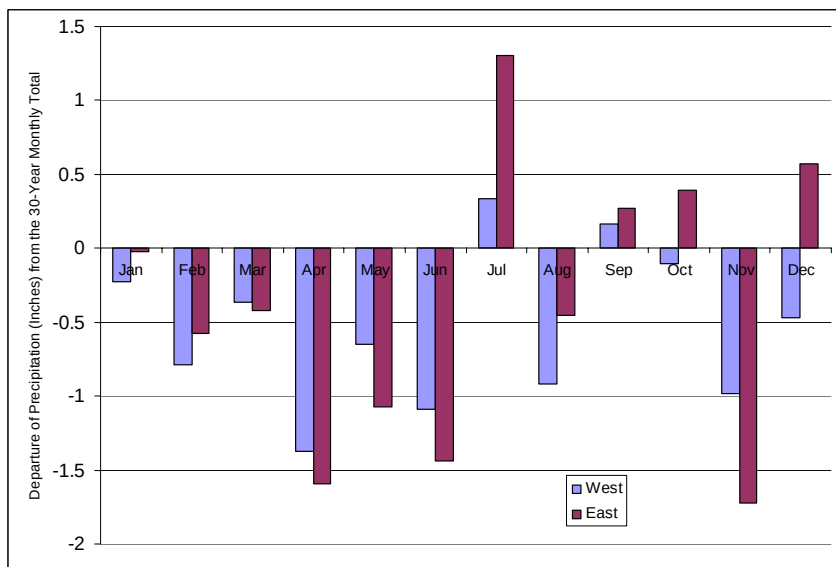


**Figure 3.6. Monthly Precipitation Departures from the 30-Year Mean for the West and East Sides of ROMO, 2006.**

A comparison of the park-level and regional precipitation anomalies (Figure 3.7) suggests the ROMO generally followed regional departures, especially on the east side ( $r = 0.84$  east;  $r = 0.59$  west). One notable exception is the month of August where ROMO did not experience the moisture surplus experienced at the regional level.

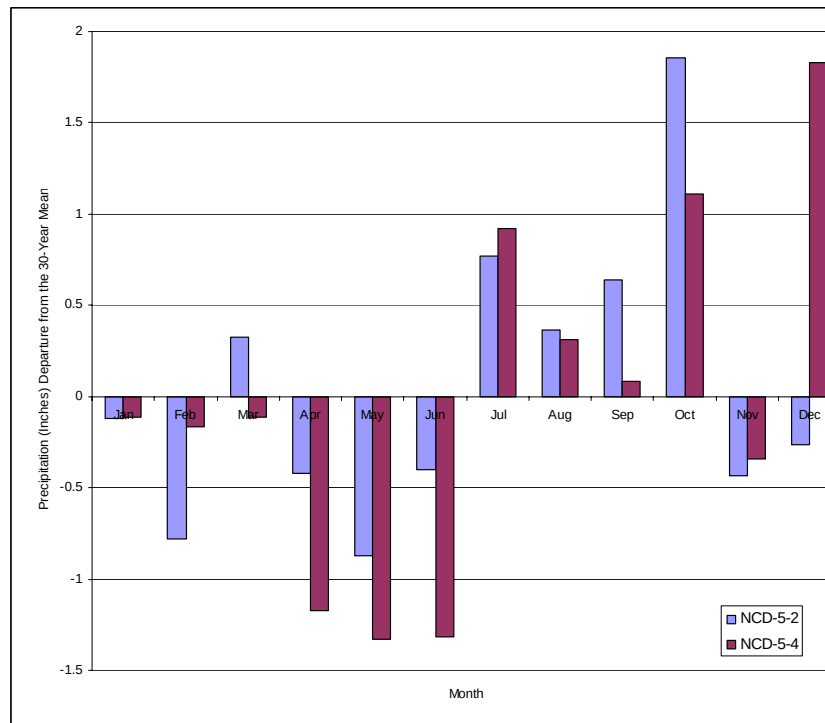


**Figure 3.7. Monthly Precipitation Anomalies for Colorado Climate Divisions 2 (West) and 4 (East), 2006.**

Figure 3.8 presents the spatial variability of precipitation departures for the 2006 season using the PRISM dataset. Both the east and west slopes of ROMO generally received below average precipitation. One notable exception is the eastern edge of the park where precipitation totals were slightly above average. Overall, about 23% of the park received above-average precipitation.

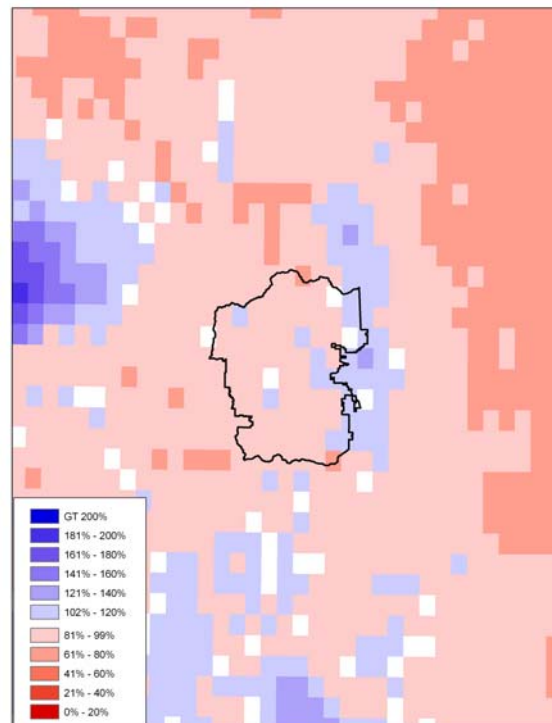


**Figure 3.8. Departure from the Mean (1970-2000) of Accumulated Precipitation for 2006 Using PRISM Dataset. Units are percent of average.**

Aggregation of the park-level precipitation indices reveals that both sides of ROMO received less than normal precipitation compared to the last 30 years (Figure 3.9;  $r=0.87$ ).

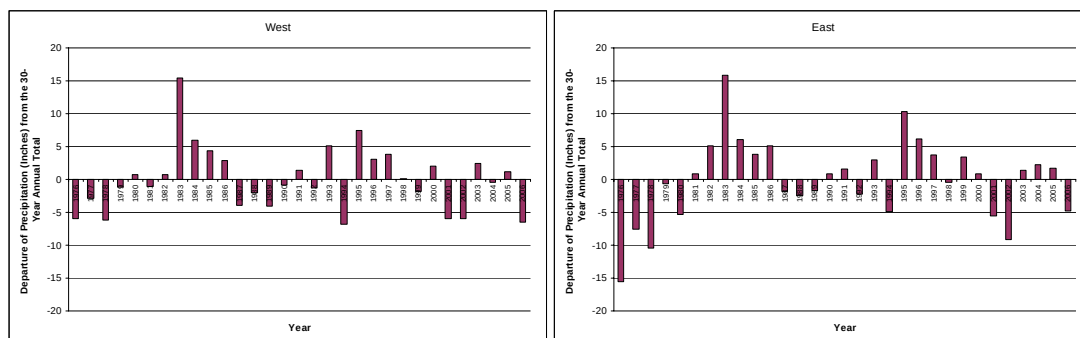


**Figure 3.9. Annual Precipitation Departures from the 30-Year Mean for the West and East Sides of ROMO, 1976-2006. Source: ROMO PPT Index.**

Figure 3.10 reveals that the both sides were comparable to regional trends, as described by the climate division precipitation departures ( $r = 0.71$  east;  $r=0.74$  west).

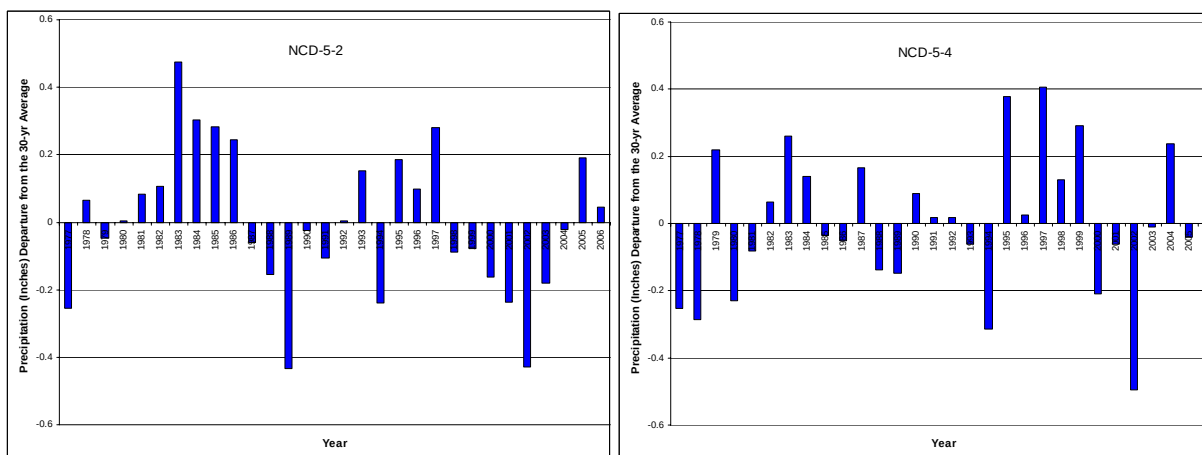


**Figure 3.10. Average Annual Precipitation Departures for Colorado Climate Divisions 2 (west) and 4 (East), 1977-2006.**

Table 3.2 lists the correlation coefficients between the monthly atmosphere/ocean indices and annual accumulated precipitation for the eastern and western slopes of ROMO. In general, relationships were not as strong as they were with temperature. In both cases, the PDO had the strongest correlation with annual precipitation, although the association was stronger for the western slope.

| <i>Index</i> | <i>East-PPT</i> | <i>West-PPT</i> |
|--------------|-----------------|-----------------|
| CPC-AMO      | 0.11            | -0.05           |
| CPC-TNH      | -0.13           | -0.15           |
| CPC-SOI      | -0.06           | -0.12           |
| CPC-PNA      | 0.21            | 0.35            |
| CPC-PDO      | <b>0.36</b>     | <b>0.49</b>     |
| CPC-NAO      | 0.10            | -0.03           |

**Table 3.2. 30-yr Annual Correlations Between the Atmospheric/Oceanic Indices and Eastern and Western Slope Annual Total Precipitation of ROMO. Highest correlations for each side of the park are bolded.**

### 3.3. Snow

For the snow year of 2006 (October 2005-June 2006), both sides of ROMO followed a similar SWE pattern (Figure 3.11;  $r = 0.81$ ). In winter (i.e., December through February) SWE ranged from 110-120+% of normal. However, by March SWE began to plummet and dropped to below normal conditions by May. This change in spring snowpack was triggered by a rapid spring warm-up coupled with little precipitation.

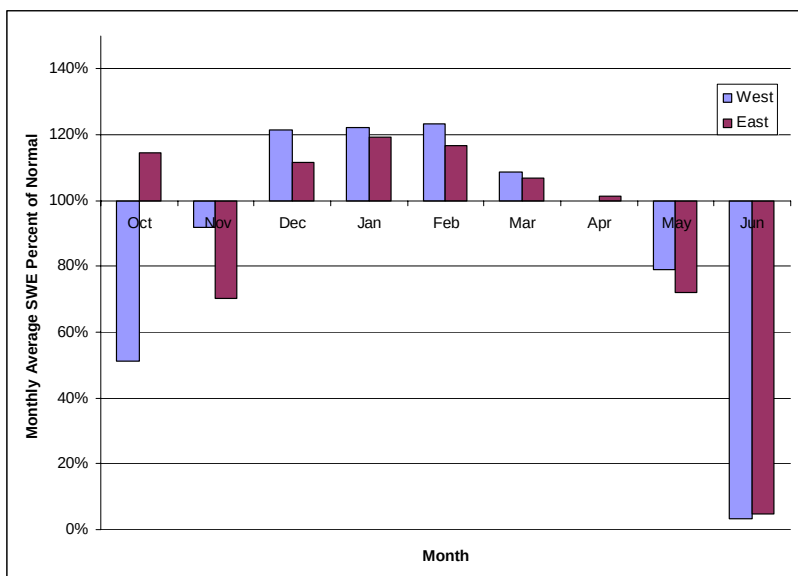


**Figure 3.11. Monthly Snow Water Equivalent Anomaly, Percent of Normal, Relative to the 30-yr Mean for 2006.**

Figure 3.12 indicates how the average basin-level SWE changed during the 2006 season in relation to the major watersheds of ROMO. SWE peaked in April, 2006. The North Platte headwaters had the highest average SWE while the St. Vrain Basin and Big Thompson had the lowest.

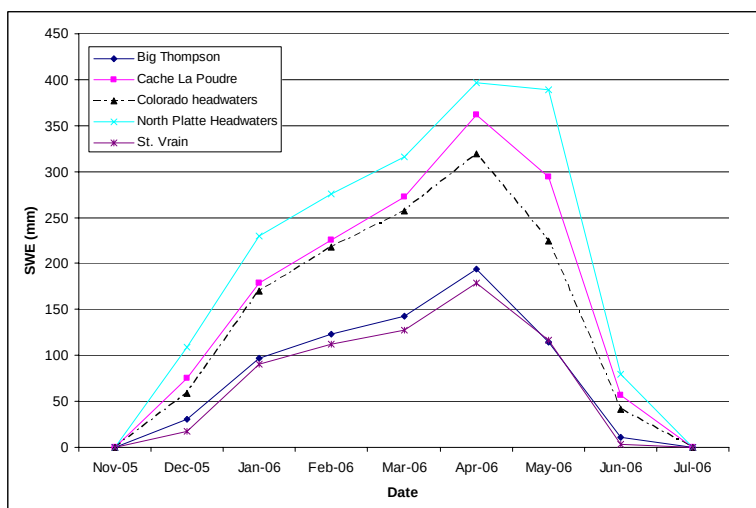


**Figure 3.12. Average SWE by Sub-Basin, November 2005-July 2006. Source: SNODAS.**

Figure 3.13 presents the distribution of SWE for April 2006, when the total integrated SWE for ROMO was at a maximum.

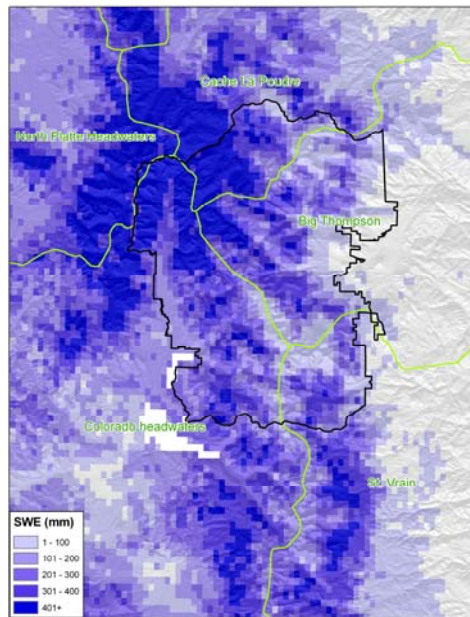


**Figure 3.13. Maximum Snow Water Equivalent (SWE) in millimeters, April 1, 2006. Superimposed on the map in green are the major watershed boundaries.**

Compared to the last 30-years, the 2006 average SWE for both sides of the divide fell slightly below average (Figure 3.14). Furthermore, SWE has been below average over the last three years. Both sides of the divide have shown similar SWE departures over the last 30 years ( $r = 0.88$ ).

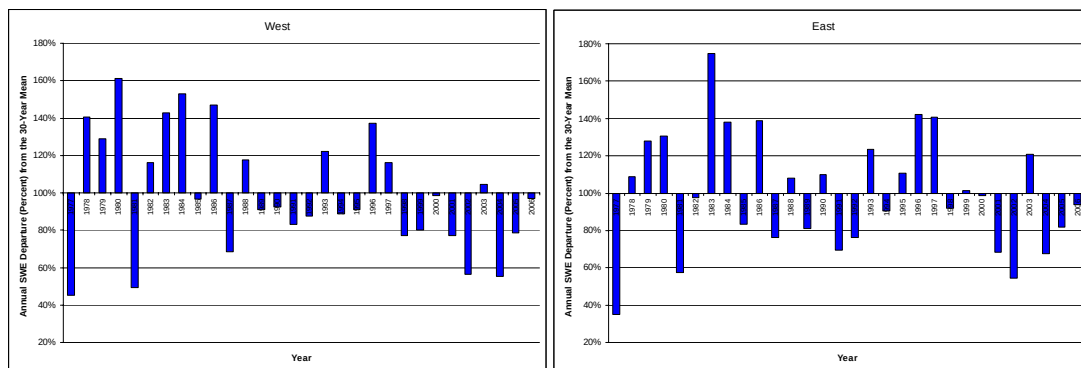


**Figure 3.14. Average Snow Water Equivalent Anomaly, Percent of Normal, for 1977-2006.**

A correlation of the annual average SWE with the ocean/atmosphere indices suggests that the AMO (west side) and PDO (east side) may influence annual snow conditions (Table 3.3).

| <i>Index</i> | <i>East Side</i> | <i>West Side</i> |
|--------------|------------------|------------------|
| CPC-AMO      | -0.13            | <b>-0.37</b>     |
| CPC-TNH      | -0.13            | 0.04             |
| CPC-SOI      | 0.07             | 0.09             |
| CPC-PNA      | 0.12             | -0.01            |
| CPC-PDO      | <b>0.41</b>      | 0.31             |
| CPC-NAO      | 0.15             | 0.16             |

**Table 3.3. 30-Year Correlation between Annual Average SWE and Atmosphere/Ocean Indices.**

### 3.4. Drought

During the first six months, the Palmer Drought Severity Index (PDSI) decreased, indicating more acute drought conditions (Figure 3.15;  $r = 0.81$ ). However, drought conditions reversed in July and tended toward a moisture surplus, especially for Division 4. This reversal coincides with the increase in July precipitation (Figures 3.6 and 3.7) and depressed temperatures in the late summer and fall.

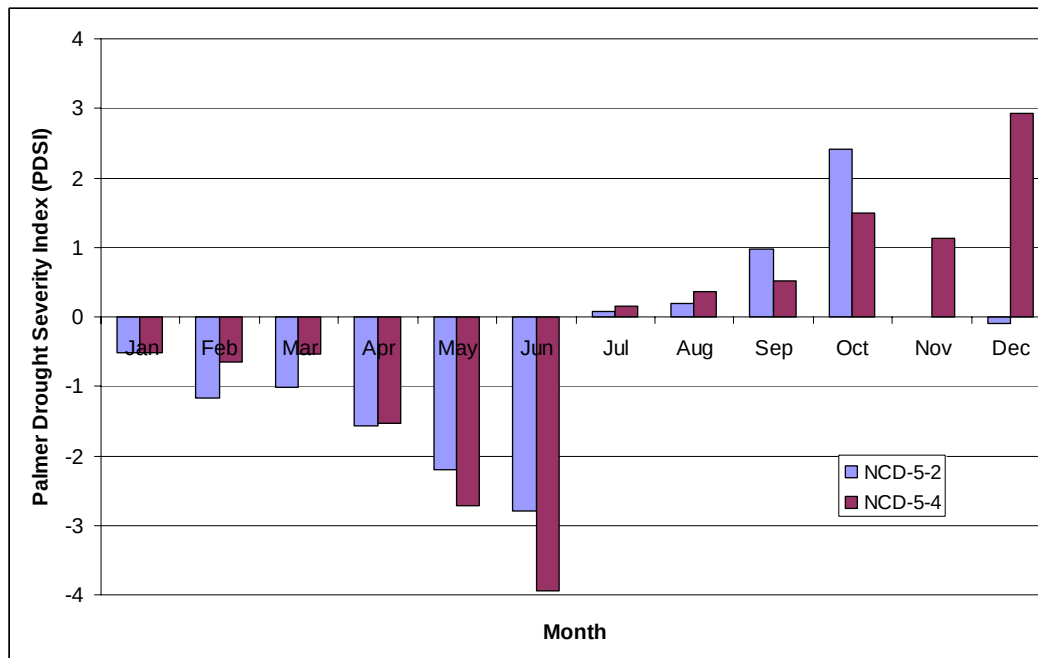


**Figure 3.15. Monthly Palmer Drought Severity Indexes for Colorado Climate Divisions 2 (West) and 4 (East), 2006**

Table 3.4 summarizes the averages all of the Climate Division and Colorado drought indices for the entire year. It indicates that all climate division drought indices were negative, i.e., average drought conditions prevailed. Only the Colorado SWSI indices were slightly positive.

| Side of ROMO                         | PDSI | ZNDX | PMDI | PHDI | CO-SWSI |
|--------------------------------------|------|------|------|------|---------|
| West Side (NCD-5-2 and South Platte) | -0.5 | -0.2 | -0.5 | -0.6 | 1.2     |
| East Side (NCD-5-4 and Colorado)     | -0.3 | -0.2 | -0.9 | -1.0 | 0.9     |

**Table 3.4. Averages for All Drought Indices, 2006.**

While both divisions experienced comparable drought episodes for the 2006, their relationship weakens when evaluated over the last 30 years ( $r = 0.75$ ). For instance, climate division 2 (West) has had prevailing drought conditions since 2000, while climate division 4 (East) had a moisture surplus.

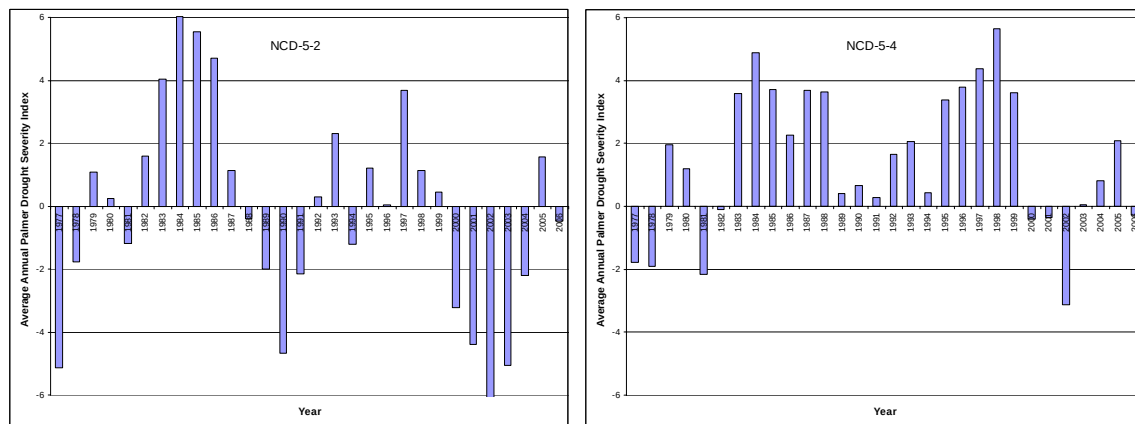


**Figure 3.16. Annual Average Palmer Drought Severity Indexes for Colorado Climate Divisions 2 (West) and 4 (East), 1977-2006**

Table 3.5 summarizes the correlation coefficients between the atmospheric and oceanic indices and regional drought. Similar to precipitation, the PDO appears to be related closely to drought on both sides of the divide, particularly on the western slope.

| <i>Index</i> | <i>CD 2 - West Side</i> | <i>CD 4- East Side</i> |
|--------------|-------------------------|------------------------|
| CPC-AMO      | -0.29                   | 0.11                   |
| CPC-TNH      | -0.16                   | -0.10                  |
| CPC-SOI      | -0.09                   | 0.09                   |
| CPC-PNA      | 0.25                    | 0.30                   |
| CPC-PDO      | <b>0.50</b>             | <b>0.35</b>            |
| CPC-NAO      | -0.02                   | -0.14                  |

**Table 3.5. 30-yr Annual Correlations Between the Atmospheric/Oceanic Indices and Eastern and Western Slope Annual Average Drought. Highest correlations are bolded.**

## 4. Conclusion

This report provided a basic summary of the 2006 weather and climate for ROMO. The objectives of this report were to (1) summarize ROMO's climate in 2006; (2) provide an inventory of data available for further analysis; (3) quantify the relationships among different spatial and temporal scales; and (4) provide a working example of a prototype report.

Foremost, this report summarized for components of ROMO's climate that are key to managing its natural resources: temperature, precipitation, snow, and drought.

Temperatures for ROMO were generally above average for the 2006 season. Higher-than-normal temperatures were particularly evident during the cooler (January, November and December) and summer (April-August) months (Figures 3.1).

Temperature deviations were not consistent within the park – higher elevations and the northeastern region were cooler than normal (Figure 3.3). Annually, temperatures have generally been above average since 1998 (Figure 3.4). Some of the annual temperature variations are likely explained by AMO and PDO ocean indices (Table 3.1).

Precipitation was below average in 2006. Except for July, October and December, monthly departures from the mean were negative (Figure 3.6). Almost 75% of the park was below average; only the extreme eastern portion received above-normal precipitation (Figure 3.7). The year 2006 represents a reversal in total accumulated precipitation for ROMO, which has generally been positive since 2003. Some of the annual variations in annual precipitation appear to be weakly related to the PDO ocean index.

Snow cover, represented by SWE, was below normal for 2006. While the months of December through February were above normal, high temperatures (Figure 3.2) coupled with low precipitation (Figure 3.6) resulted in a rapid loss of SWE in the spring (Figure 3.10). Compared to the last 30-years, average SWE was slightly below normal and continues a general normal to below-average trend since 1998 (Figure 3.13). Some of the annual SWE variations may be explained by the AMO and PDO for the west and east sides of the park, respectively.

In addition, this report investigated the relationships among different spatial and temporal scales of climate. First, it quantified, using correlation coefficients as a basic metric, how comparable conditions were between the east and west sides of ROMO, both intra-annually (i.e., for 2006) and inter-annually (i.e., the last 30 years). For 2006,

both sides were generally comparable; however, at inter-annual time scales, their relationships were considerably weaker. This indicates that 2006 might not be representative of other years. How these relationships hold in the future will be revealed in future analyses and reports.

Second, this report quantified how conditions within ROMO compared to regional climate variations (both intra-seasonally and inter-annually). This was done by correlating the temperature index for ROMO with the broader climate division indices. Relationships were generally strong, which suggests that climate variations greater than the monthly time scale are homogenous regionally. Thus, the climate division indices appear to be adequate for describing ROMO's long-term climate.

Finally, this report evaluated how closely correlated annual climate of ROMO was with the atmospheric and ocean indices. This analysis was conducted only at the annual time scale and represents an extremely coarse baseline of the relationships between the ocean, atmosphere and surface environment. Nevertheless, even this basic analysis reveals and confirms important relationships, especially among the AMO and PDO. Further analyses, which evaluate individual months or seasons and which consider time lags and compounding interactions among indices, are likely to yield significantly more robust results.

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## **6. Appendices**

## ***6.1. Appendix A: Supplementary Tables***

| Station ID                            | Elevation (m) | In Park?   | Distance To Park (km) | Side Of Divide | Begin       | End         | Status        |
|---------------------------------------|---------------|------------|-----------------------|----------------|-------------|-------------|---------------|
| <b>NRCS-SC-Deer Ridge</b>             | <b>2743</b>   | <b>Yes</b> | <b>0</b>              | <b>East</b>    | <b>1949</b> | <b>2006</b> | <b>Active</b> |
| <b>NRCS-SC-Hidden Valley</b>          | <b>2890</b>   | <b>Yes</b> | <b>0</b>              | <b>East</b>    | <b>1941</b> | <b>2006</b> | <b>Active</b> |
| <b>NRCS-SC-Longs Peak</b>             | <b>3200</b>   | <b>Yes</b> | <b>0</b>              | <b>East</b>    | <b>1951</b> | <b>2006</b> | <b>Active</b> |
| <b>NRCS-SC-Wild Basin</b>             | <b>2926</b>   | <b>Yes</b> | <b>0</b>              | <b>East</b>    | <b>1936</b> | <b>2006</b> | <b>Active</b> |
| <b>SNOTEL-05j18s</b>                  | <b>2621</b>   | <b>Yes</b> | <b>0</b>              | <b>East</b>    | <b>1980</b> | <b>2006</b> | <b>Active</b> |
| <b>SNOTEL-05j39s</b>                  | <b>2896</b>   | <b>Yes</b> | <b>0</b>              | <b>East</b>    | <b>1980</b> | <b>2006</b> | <b>Active</b> |
| <b>SNOTEL-05j40s</b>                  | <b>3261</b>   | <b>Yes</b> | <b>0</b>              | <b>East</b>    | <b>1979</b> | <b>2006</b> | <b>Active</b> |
| <b>COOP-Grand Lake 1 NW</b>           | <b>2658</b>   | <b>Yes</b> | <b>0</b>              | <b>West</b>    | <b>1907</b> | <b>2007</b> | <b>Active</b> |
| <b>NRCS-SC-Lake Irene</b>             | <b>3261</b>   | <b>Yes</b> | <b>0</b>              | <b>West</b>    | <b>1938</b> | <b>2006</b> | <b>Active</b> |
| <b>NRCS-SC-Milner Pass</b>            | <b>2972</b>   | <b>Yes</b> | <b>0</b>              | <b>West</b>    | <b>1952</b> | <b>2006</b> | <b>Active</b> |
| <b>NRCS-SC-North Inlet Grand Lake</b> | <b>2743</b>   | <b>Yes</b> | <b>0</b>              | <b>West</b>    | <b>1938</b> | <b>2006</b> | <b>Active</b> |
| <b>SNOTEL-05j04s</b>                  | <b>2752</b>   | <b>Yes</b> | <b>0</b>              | <b>West</b>    | <b>1980</b> | <b>2006</b> | <b>Active</b> |
| <b>SNOTEL-05j10s</b>                  | <b>3261</b>   | <b>Yes</b> | <b>0</b>              | <b>West</b>    | <b>1978</b> | <b>2006</b> | <b>Active</b> |
| COOP-Estes Park 1 SSE                 | 2373          | No         | 2                     | East           | 2001        | 2007        | Active        |
| COOP-Flatiron                         | 1678          | No         | 22                    | East           | 1996        | 2007        | Active        |
| COOP-Gould 4 SE S F S P               | 2743          | No         | 10                    | East           | 2000        | 2007        | Active        |
| COOP-Gross Reservoir                  | 2429          | No         | 32                    | East           | 1978        | 2007        | Active        |
| COOP-Hourglass Reservoir              | 2902          | No         | 5                     | East           | 1988        | 2007        | Active        |
| COOP-Waterdale                        | 1594          | No         | 24                    | East           | 1902        | 2007        | Active        |
| NRCS-SC-Baltimore                     | 2682          | No         | 29                    | East           | 1961        | 2006        | Active        |
| NRCS-SC-Bennett Creek                 | 2804          | No         | 14                    | East           | 1966        | 2006        | Active        |
| NRCS-SC-Big South                     | 2621          | No         | 10                    | East           | 1936        | 2006        | Active        |
| NRCS-SC-Boulder Falls                 | 3048          | No         | 16                    | East           | 1952        | 2006        | Active        |
| NRCS-SC-Cameron Pass                  | 3135          | No         | 1                     | East           | 1936        | 2006        | Active        |
| NRCS-SC-Chambers Lake                 | 2743          | No         | 11                    | East           | 1936        | 2006        | Active        |
| NRCS-SC-Deadman Hill                  | 3115          | No         | 28                    | East           | 1937        | 2006        | Active        |
| NRCS-SC-Hourglass Lake                | 2853          | No         | 5                     | East           | 1938        | 2006        | Active        |
| NRCS-SC-Mc Intyre                     | 2774          | No         | 31                    | East           | 1949        | 2006        | Active        |
| NRCS-SC-Park View                     | 2792          | No         | 16                    | East           | 1936        | 2006        | Active        |
| NRCS-SC-Red Feather                   | 2743          | No         | 30                    | East           | 1949        | 2006        | Active        |
| NRCS-SC-Sawtooth                      | 2969          | No         | 3                     | East           | 2002        | 2006        | Active        |
| NRCS-SC-University Camp               | 3139          | No         | 14                    | East           | 1938        | 2006        | Active        |
| NRCS-SC-Ward                          | 2896          | No         | 12                    | East           | 1950        | 2006        | Active        |
| NRCS-SC-Willow Creek Pass             | 2908          | No         | 16                    | East           | 1938        | 2006        | Active        |
| SNOTEL-05j06s                         | 3115          | No         | 28                    | East           | 1978        | 2006        | Active        |
| SNOTEL-05j08s                         | 3139          | No         | 14                    | East           | 1978        | 2006        | Active        |
| SNOTEL-05j37s                         | 3085          | No         | 6                     | East           | 1978        | 2006        | Active        |
| SNOTEL-05j41s                         | 2957          | No         | 25                    | East           | 1978        | 2006        | Active        |
| SNOTEL-05j42s                         | 3021          | No         | 14                    | East           | 1980        | 2006        | Active        |
| SNOTEL-06j05s                         | 2908          | No         | 16                    | East           | 1978        | 2006        | Active        |
| COOP-Grand Lake 6 SSW                 | 2526          | No         | 3                     | West           | 1948        | 2007        | Active        |
| NRCS-SC-Berthoud Pass                 | 2957          | No         | 37                    | West           | 1936        | 2006        | Active        |
| NRCS-SC-Corral Creek                  | 2957          | No         | 27                    | West           | 1995        | 2006        | Active        |
| NRCS-SC-Granby                        | 2621          | No         | 15                    | West           | 1949        | 2006        | Active        |
| NRCS-SC-Lapland                       | 2835          | No         | 32                    | West           | 1938        | 2006        | Active        |
| NRCS-SC-Ranch Creek                   | 2865          | No         | 26                    | West           | 1957        | 2006        | Active        |
| NRCS-SC-Vasquez                       | 2926          | No         | 35                    | West           | 1957        | 2006        | Active        |
| SNOTEL-05j12s                         | 2658          | No         | 7                     | West           | 1985        | 2006        | Active        |
| SNOTEL-05k06s                         | 2950          | No         | 27                    | West           | 1978        | 2006        | Active        |
| COOP-Allenspark 3 NW                  | 2591          | No         | 1                     | East           | 1994        | 2004        | Inactive      |
| COOP-Caribou Ranch                    | 2550          | No         | 19                    | East           | 1962        | 1970        | Inactive      |
| COOP-Estes Park                       | 2280          | No         | 3                     | East           | 1896        | 1922        | Inactive      |
| COOP-Glen Comfort                     | 2240          | No         | 4                     | East           | 1995        | 1999        | Inactive      |
| COOP-Glendevey                        | 2522          | No         | 31                    | East           | 1917        | 1958        | Inactive      |
| COOP-Hawthorne                        | 1806          | No         | 36                    | East           | 1908        | 1976        | Inactive      |
| COOP-Nederland 2 NNE                  | 2512          | No         | 21                    | East           | 1970        | 1974        | Inactive      |
| COOP-Red Feather Lakes                | 2530          | No         | 29                    | East           | 1991        | 1996        | Inactive      |
| COOP-Red Feather Lks 2 SE             | 2489          | No         | 28                    | East           | 1941        | 1954        | Inactive      |
| COOP-Silver Lake                      | 3158          | No         | 14                    | East           | 1910        | 1933        | Inactive      |
| COOP-Hot Sulphur Springs              | 2318          | No         | 30                    | West           | 1941        | 1981        | Inactive      |
| COOP-Parshall 10 SSE                  | 2522          | No         | 38                    | West           | 1951        | 1973        | Inactive      |
| COOP-Allenspark 2 SE                  | 2504          | No         | 3                     | East           | 1944        | 1993        | Unknown       |
| COOP-Arriba                           | 1638          | No         | 29                    | East           | 1907        | 1916        | Unknown       |
| COOP-Boulder                          | 1672          | No         | 32                    | East           | 1893        | 1906        | Unknown       |
| COOP-Boulder 2                        | 1650          | No         | 28                    | East           | 1948        | 1951        | Unknown       |
| COOP-Coal Creek Canyon                | 2728          | No         | 34                    | East           | 1994        | 2004        | Unknown       |
| COOP-Longmont 2 ESE                   | 1509          | No         | 39                    | East           | 1893        | 2004        | Unknown       |
| COOP-Longmont 6 NW                    | 1570          | No         | 31                    | East           | 1948        | 1951        | Unknown       |
| COOP-Loveland 2 N                     | 1548          | No         | 35                    | East           | 1989        | 1994        | Unknown       |
| COOP-Rustic 9 WSW                     | 2347          | No         | 16                    | East           | 1993        | 2001        | Unknown       |
| COOP-Fraser1                          | 2609          | No         | 25                    | West           | 1908        | 1937        | Unknown       |
| COOP-Williams Fork Dam                | 2322          | No         | 36                    | West           | 1982        | 1993        | Unknown       |
| COOP-Winter Park                      | 2775          | No         | 30                    | West           | 1942        | 1948        | Unknown       |

**Table A-1. Current Data Inventory for Active and Inactive Weather Stations within and Around ROMO. Active stations within the park are in bold.**

| Station    | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Summary |
|------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|---------|
| COOP-Estes | 52  | 56  | 59  | 71  | 80  | 88  | 92  | 85  | 75  | 72  | 61  | 50  | 92      |
| Park 1 SSE | 13  | -4  | 14  | 26  | 34  | 51  | 50  | 51  | 36  | 24  | 4   | 5   | 25      |
|            | 3   | -13 | 1   | 19  | 27  | 39  | 46  | 35  | 26  | 13  | -7  | -7  | -13     |
| COOP-      | 46  | 46  | 51  | 63  | 69  | 76  | 83  | 76  | 71  | 68  | 56  | 43  | 83      |
| Gould 4 SE | -1  | -8  | 8   | 17  | 30  | 45  | 49  | 37  | 23  | 16  | -9  | -3  | 17      |
| S F S P    | -18 | -24 | -9  | 6   | 13  | 28  | 34  | 28  | 12  | 4   | -24 | -20 | -24     |
| COOP-      | 48  | 52  | 54  | 69  | 75  | 83  | 89  | 80  | 75  | 69  | 61  | 46  | 89      |
| Grand Lake | 5   | -3  | 16  | 30  | 36  | 49  | 54  | 51  | 31  | 19  | 0   | 3   | 24      |
| 1 NW       | -15 | -23 | -5  | 14  | 17  | 30  | 37  | 30  | 21  | 7   | -18 | -17 | -23     |
| COOP-      | 42  | 52  | 52  | 66  | 76  | 83  | 88  | 82  | 78  | 69  | 59  | 45  | 88      |
| Grand Lake | -2  | -7  | 12  | 29  | 37  | 49  | 56  | 52  | 33  | 20  | 2   | 1   | 24      |
| 6 SSW      | -23 | -28 | -9  | 12  | 18  | 31  | 38  | 32  | 22  | 9   | -12 | -16 | -28     |
| COOP-      | 59  | 60  | 66  | 75  | 84  | 92  | 91  | 86  | 77  | 74  | 70  | 61  | 92      |
| Gross      | 15  | -5  | 16  | 25  | 37  | 53  | 50  | 54  | 37  | 27  | 4   | 6   | 27      |
| Reservoir  | 6   | -16 | 6   | 20  | 23  | 39  | 45  | 40  | 27  | 16  | -9  | -5  | -16     |
| COOP-      | 46  | 49  | 53  | 62  | 72  | 81  | 85  | 79  | 73  | 67  | 56  | 47  | 85      |
| Hourglass  | 9   | 0   | 11  | 20  | 28  | 46  | 45  | 43  | 30  | 19  | -1  | 3   | 21      |
| Reservoir  | -3  | -10 | 0   | 11  | 15  | 29  | 39  | 32  | 22  | 11  | -11 | -9  | -11     |
| COOP-      | 71  | 71  | 70  | 84  | 91  | 101 | 102 | 94  | 86  | 84  | 77  | 64  | 102     |
| Waterdale  | 24  | -4  | 21  | 33  | 41  | 61  | 57  | 57  | 45  | 31  | 11  | 15  | 33      |
|            | 12  | -14 | 9   | 26  | 31  | 46  | 52  | 45  | 32  | 20  | -2  | 4   | -14     |
| SNOTEL-    | 47  | 51  | 53  | 64  | 71  | 78  | 83  | 77  | 71  |     |     |     |         |
| 05j04s     | 8   | -3  | 15  | 24  | 32  | 44  | 51  | 43  | 33  |     |     |     |         |
|            | -9  | -21 | -2  | 14  | 20  | 31  | 39  | 33  | 26  |     |     |     |         |
| SNOTEL-    | 40  | 38  | 46  | 60  | 67  | 75  | 80  | 76  | 100 |     |     |     |         |
| 05j06s     | 2   | -5  | 5   | 17  | 25  | 40  | 42  | 38  | 27  |     |     |     |         |
|            | -6  | -19 | -8  | 8   | 7   | 27  | 36  | 23  | 13  |     |     |     |         |
| SNOTEL-    | 46  | 44  | 52  | 60  | 65  | 73  | 78  | 73  | 67  |     |     |     |         |
| 05j08s     | 8   | 3   | 10  | 20  | 29  | 41  | 45  | 42  | 28  |     |     |     |         |
|            | 0   | -4  | 1   | 13  | 19  | 30  | 38  | 31  | 23  |     |     |     |         |
| SNOTEL-    | 49  | 48  | 50  | 60  | 65  | 76  | 76  | 71  | 66  |     |     |     |         |
| 05j10s     | 6   | -3  | 9   | 18  | 27  | 40  | 46  | 38  | 27  |     |     |     |         |
|            | -5  | -19 | -1  | 11  | 11  | 31  | 39  | 32  | 19  |     |     |     |         |
| SNOTEL-    | 47  | 56  | 59  | 67  | 77  | 86  | 84  | 79  | 74  |     |     |     |         |
| 05j12s     | 10  | 2   | 16  | 27  | 35  | 46  | 52  | 44  | 33  |     |     |     |         |
|            | -5  | -15 | 4   | 17  | 24  | 32  | 41  | 36  | 22  |     |     |     |         |
| SNOTEL-    | 53  | 53  | 56  | 68  | 74  | 82  | 85  | 81  | 74  |     |     |     |         |
| 05j18s     | 15  | -3  | 16  | 28  | 36  | 49  | 50  | 47  | 36  |     |     |     |         |
|            | 5   | -14 | 3   | 19  | 25  | 36  | 45  | 38  | 29  |     |     |     |         |
| SNOTEL-    | 50  | 50  | 56  | 65  | 74  | 80  | 87  | 79  | 73  |     |     |     |         |
| 05j37s     | 9   | 1   | 11  | 20  | 29  | 43  | 47  | 38  | 28  |     |     |     |         |
|            | 2   | -16 | -4  | 8   | 15  | 26  | 36  | 30  | 21  |     |     |     |         |
| SNOTEL-    | 45  | 46  | 49  | 60  | 68  | 76  | 81  | 74  | 68  |     |     |     |         |
| 05j39s     | 11  | 2   | 13  | 23  | 33  | 46  | 47  | 45  | 32  |     |     |     |         |
|            | 5   | -8  | 7   | 17  | 26  | 35  | 44  | 39  | 28  |     |     |     |         |
| SNOTEL-    | 82  | 87  | 96  | 100 | 109 | 115 | 113 | 114 | 111 |     |     |     |         |
| 05j40s     | 5   | -2  | 9   | 17  | 26  | 41  | 44  | 38  | 27  |     |     |     |         |
|            | -9  | -20 | -10 | 1   | 13  | 24  | 29  | 20  | 11  |     |     |     |         |
| SNOTEL-    | 47  | 49  | 53  | 62  | 70  | 77  | 81  | 75  | 69  |     |     |     |         |
| 05j41s     | 11  | 5   | 13  | 23  | 31  | 45  | 47  | 45  | 31  |     |     |     |         |
|            | 6   | -7  | 6   | 15  | 23  | 36  | 44  | 39  | 24  |     |     |     |         |
| SNOTEL-    | 76  | 72  | 93  | 94  | 94  | 110 | 116 | 106 | 107 |     |     |     |         |
| 05j42s     | 11  | 4   | 12  | 23  | 31  | 43  | 46  | 43  | 31  |     |     |     |         |
|            | -3  | -5  | 0   | 8   | 16  | 19  | 33  | 26  | 12  |     |     |     |         |
| SNOTEL-    | 42  | 47  | 50  | 62  | 70  | 78  | 82  | 75  | 71  |     |     |     |         |
| 05k06s     | 10  | 4   | 12  | 22  | 32  | 44  | 50  | 43  | 29  |     |     |     |         |
|            | 3   | -8  | 6   | 15  | 24  | 37  | 43  | 37  | 22  |     |     |     |         |
| SNOTEL-    | 41  | 46  | 49  | 62  | 70  | 76  | 80  | 71  | 67  |     |     |     |         |
| 06j05s     | 1   | -8  | 7   | 19  | 27  | 41  | 50  | 41  | 28  |     |     |     |         |
|            | -17 | -26 | -8  | 5   | 12  | 23  | 36  | 30  | 16  |     |     |     |         |

**Table A-2. Maximum (red), Average (black) and Minimum (blue) Temperatures (Fahrenheit) for Each Month by Station, 2006. Temperatures are rounded to the nearest whole degree.**

| Station                  | # Frost Free Days | Last Frost of Spring | First Frost of Fall |
|--------------------------|-------------------|----------------------|---------------------|
| SNOTEL-05j40s            | 9                 | 7/13                 | 7/22                |
| SNOTEL-05j42s            | 42                | 6/30                 | 8/11                |
| COOP-Gould 4 SE S F S P  | 45                | 6/28                 | 8/12                |
| SNOTEL-05j06s            | 61                | 6/27                 | 8/27                |
| SNOTEL-05j08s            | 62                | 6/27                 | 8/28                |
| SNOTEL-05j37s            | 62                | 6/27                 | 8/28                |
| SNOTEL-06j05s            | 62                | 6/28                 | 8/29                |
| COOP-Grand Lake 1 NW     | 63                | 6/26                 | 8/28                |
| COOP-Hourglass Reservoir | 64                | 6/24                 | 8/27                |
| COOP-Grand Lake 6 SSW    | 65                | 6/24                 | 8/28                |
| SNOTEL-05j10s            | 67                | 6/27                 | 9/2                 |
| SNOTEL-05j04s            | 77                | 6/18                 | 9/3                 |
| SNOTEL-05j12s            | 108               | 5/31                 | 9/16                |
| COOP-Estes Park 1 SSE    | 109               | 5/16                 | 9/2                 |
| SNOTEL-05j41s            | 109               | 5/30                 | 9/16                |
| SNOTEL-05k06s            | 109               | 5/30                 | 9/16                |
| SNOTEL-05j39s            | 123               | 5/16                 | 9/16                |
| COOP-Gross Reservoir     | 126               | 5/15                 | 9/18                |
| SNOTEL-05j18s            | 128               | 5/12                 | 9/17                |
| COOP-Waterdale           | 129               | 5/11                 | 9/17                |

**Table A-3. Number of Frost Free Days, First and Last Frost Dates for Active Stations Within and Around ROMO. Sorted in Ascending Order by the Number of Frost Free Days<sup>1</sup>.**

| Station                  | Jan  | Feb  | Mar  | Apr | May | Jun | Jul | Aug | Sep | Oct  | Nov  | Dec  |
|--------------------------|------|------|------|-----|-----|-----|-----|-----|-----|------|------|------|
| COOP-Estes Park 1 SSE    | 1102 | 1103 | 1060 | 664 | 410 | 102 | 55  | 108 | 461 | 696  | 866  | 1192 |
|                          | 0    | 0    | 0    | 0   | 1   | 29  | 82  | 36  | 0   | 0    | 0    | 0    |
| COOP-Gould 4 SE S F S P  | 1422 | 1454 | 1267 | 898 | 701 | 423 | 263 | 389 | 551 | 1004 | 1230 | 1400 |
|                          | 0    | 0    | 0    | 0   | 0   | 0   | 0   | 0   | 0   | 0    | 0    | 0    |
| COOP-Grand Lake 1 NW     | 1399 | 1305 | 1160 | 764 | 570 | 275 | 135 | 224 | 576 | 848  | 1102 | 1390 |
|                          | 0    | 0    | 0    | 0   | 0   | 0   | 4   | 0   | 0   | 0    | 0    | 0    |
| COOP-Grand Lake 6 SSW    | 1581 | 1466 | 1253 | 784 | 535 | 254 | 107 | 169 | 522 | 819  | 1089 | 1447 |
|                          | 0    | 0    | 0    | 0   | 0   | 0   | 11  | 0   | 0   | 0    | 0    | 0    |
| COOP-Gross Reservoir     | 1006 | 1052 | 1010 | 624 | 394 | 87  | 52  | 87  | 416 | 636  | 829  | 1121 |
|                          | 0    | 0    | 0    | 0   | 3   | 20  | 84  | 44  | 0   | 0    | 0    | 0    |
| COOP-Hourglass Reservoir | 1341 | 1282 | 1222 | 861 | 641 | 292 | 171 | 273 | 615 | 883  | 1040 | 1348 |
|                          | 0    | 0    | 0    | 0   | 0   | 0   | 13  | 1   | 0   | 0    | 0    | 0    |
| COOP-Waterdale           | 838  | 966  | 870  | 418 | 204 | 14  | 8   | 15  | 211 | 488  | 744  | 1013 |
|                          | 0    | 0    | 0    | 0   | 34  | 206 | 310 | 208 | 10  | 2    | 0    | 0    |

**Table A-4. Total of Heating Degree Days (red) and Cooling Degree (blue) for Active Stations Within and Around ROMO, 2006.**

<sup>1</sup> Special thanks to Simon Kingston for development of a T-SQL Stored Procedure.

| Station                  | Jan                | Feb                | Mar                | Apr                | May                | Jun                | Jul                | Aug                | Sep                | Oct                | Nov                | Dec                | Summary              |
|--------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|----------------------|
| COOP-Estes Park 1 SSE    | 0.25<br>0.44<br>14 | 0.31<br>0.74<br>12 | 0.28<br>1.50<br>17 | 0.33<br>0.80<br>13 | 0.59<br>1.33<br>14 | 0.23<br>0.50<br>11 | 1.51<br>4.74<br>21 | 0.66<br>2.23<br>24 | 0.35<br>1.54<br>13 | 1.05<br>2.13<br>13 | 0.21<br>0.48<br>10 | 1.13<br>2.58<br>13 | 1.51<br>19.01<br>175 |
| COOP-Flatiron            | 0.11<br>0.11<br>2  |                    | 0.48<br>1.13<br>7  | 0.12<br>0.22<br>3  | 0.32<br>1.21<br>9  | 0.11<br>0.23<br>4  | 1.74<br>3.46<br>12 | 0.52<br>0.96<br>9  | 0.21<br>0.45<br>5  | 0.91<br>2.09<br>4  | 0.45<br>0.48<br>2  | 0.31<br>0.34<br>2  | 1.74<br>10.69<br>59  |
| COOP-Gould 4 SE S F S P  | 0.15<br>1.28<br>18 | 0.14<br>0.73<br>13 | 0.45<br>2.49<br>16 | 0.75<br>1.87<br>12 | 0.64<br>2.29<br>13 | 0.30<br>0.67<br>5  | 0.50<br>2.91<br>17 | 0.80<br>2.80<br>12 | 0.60<br>2.38<br>11 | 1.00<br>2.07<br>19 | 0.34<br>1.96<br>10 | 1.67<br>2.38<br>13 | 1.67<br>23.85<br>159 |
| COOP-Grand Lake 1 NW     | 0.25<br>1.54<br>20 | 0.17<br>0.74<br>11 | 0.37<br>1.09<br>19 | 0.23<br>0.68<br>13 | 0.68<br>1.26<br>13 | 0.19<br>0.47<br>8  | 0.45<br>2.26<br>19 | 0.57<br>1.80<br>22 | 0.61<br>1.37<br>15 | 0.55<br>1.60<br>15 | 0.47<br>1.35<br>12 | 0.62<br>1.63<br>16 | 0.68<br>15.80<br>183 |
| COOP-Grand Lake 6 SSW    | 0.18<br>0.53<br>18 | 0.09<br>0.25<br>10 | 0.28<br>0.80<br>16 | 0.21<br>0.71<br>10 | 0.59<br>1.34<br>14 | 0.37<br>0.67<br>7  | 0.45<br>2.05<br>16 | 0.28<br>1.18<br>13 | 0.70<br>1.39<br>9  | 0.40<br>0.90<br>14 | 0.15<br>0.54<br>11 | 0.51<br>1.09<br>13 | 0.70<br>11.44<br>151 |
| COOP-Gross Reservoir     | 0.22<br>0.31<br>3  | 0.30<br>0.61<br>4  | 0.34<br>1.70<br>10 | 0.35<br>1.04<br>5  | 0.18<br>0.95<br>9  | 0.11<br>0.28<br>6  | 1.46<br>3.85<br>14 | 0.33<br>1.66<br>15 | 0.56<br>1.60<br>9  | 1.20<br>3.16<br>7  | 0.53<br>0.81<br>3  | 1.95<br>3.90<br>10 | 1.95<br>19.87<br>95  |
| COOP-Hourglass Reservoir | 0.18<br>1.17<br>24 | 0.17<br>0.99<br>17 | 0.46<br>1.99<br>21 | 0.30<br>1.31<br>18 | 0.61<br>1.91<br>21 | 0.09<br>0.25<br>14 | 0.50<br>2.39<br>19 | 0.52<br>1.85<br>22 | 0.32<br>1.35<br>15 | 0.92<br>2.50<br>21 | 0.29<br>1.07<br>17 | 1.98<br>3.14<br>22 | 1.98<br>19.92<br>231 |
| COOP-Waterdale           | 0.12<br>0.12<br>1  | 0.33<br>0.61<br>5  | 0.34<br>1.26<br>9  | 0.15<br>0.17<br>2  | 0.28<br>0.78<br>5  | 0.10<br>0.18<br>3  | 0.85<br>2.14<br>5  | 1.21<br>2.01<br>10 | 0.16<br>0.35<br>5  | 0.89<br>2.62<br>7  | 0.50<br>0.71<br>5  | 1.25<br>2.18<br>6  | 1.25<br>13.14<br>63  |
| SNOTEL-05j04s            | 0.30<br>2.10<br>14 | 0.30<br>1.50<br>9  | 0.30<br>2.10<br>15 | 0.20<br>0.50<br>3  | 0.60<br>1.80<br>7  | 0.20<br>0.20<br>1  | 0.30<br>2.10<br>15 | 0.30<br>0.90<br>6  | 0.50<br>2.00<br>8  |                    |                    |                    |                      |
| SNOTEL-05j06s            | 0.40<br>2.20<br>17 | 0.30<br>2.10<br>15 | 0.50<br>3.40<br>17 | 0.70<br>2.50<br>15 | 0.60<br>1.90<br>8  | 0.10<br>0.30<br>3  | 0.50<br>2.10<br>11 | 0.50<br>1.40<br>5  | 0.60<br>2.90<br>10 |                    |                    |                    |                      |
| SNOTEL-05j08s            | 0.90<br>4.00<br>16 | 0.60<br>2.40<br>12 | 0.40<br>3.60<br>20 | 0.90<br>2.80<br>12 | 0.50<br>2.10<br>11 | 0.10<br>0.30<br>3  | 1.80<br>4.40<br>11 | 0.20<br>1.20<br>11 | 0.80<br>2.80<br>12 |                    |                    |                    |                      |
| SNOTEL-05j10s            | 0.50<br>3.40<br>16 | 0.40<br>1.90<br>8  | 0.90<br>3.40<br>16 | 0.40<br>2.30<br>11 | 0.70<br>2.40<br>11 | 0.20<br>0.30<br>2  | 0.50<br>3.00<br>13 | 0.30<br>1.00<br>7  | 0.40<br>2.60<br>10 |                    |                    |                    |                      |
| SNOTEL-05j12s            | 0.20<br>1.30<br>10 | 0.20<br>0.90<br>6  | 0.20<br>0.90<br>7  | 0.20<br>1.20<br>8  | 0.30<br>2.10<br>11 | 0.40<br>0.90<br>5  | 0.50<br>1.70<br>10 | 0.20<br>1.00<br>8  | 0.30<br>1.20<br>7  |                    |                    |                    |                      |
| SNOTEL-05j18s            | 0.50<br>1.80<br>10 | 0.40<br>1.20<br>8  | 0.80<br>2.80<br>17 | 0.60<br>2.10<br>9  | 0.60<br>2.10<br>9  | 0.20<br>0.60<br>5  | 1.30<br>4.90<br>13 | 0.40<br>1.80<br>10 | 0.40<br>1.70<br>9  |                    |                    |                    |                      |
| SNOTEL-05j37s            | 0.50<br>3.40<br>15 | 1.00<br>2.60<br>10 | 0.50<br>3.90<br>21 | 0.90<br>3.00<br>13 | 0.60<br>3.20<br>13 | 0.30<br>0.80<br>4  | 0.80<br>4.90<br>14 | 0.70<br>2.60<br>9  | 0.80<br>4.70<br>13 |                    |                    |                    |                      |
| SNOTEL-05j39s            | 0.40<br>2.70<br>16 | 0.60<br>2.20<br>13 | 0.50<br>2.60<br>15 | 0.60<br>2.30<br>15 | 0.40<br>2.40<br>16 | 0.10<br>0.10<br>1  | 0.80<br>1.30<br>5  | 0.30<br>0.90<br>6  | 0.50<br>2.00<br>8  |                    |                    |                    |                      |
| SNOTEL-05j40s            | 0.50<br>3.60<br>17 | 0.80<br>2.10<br>8  | 1.00<br>3.70<br>16 | 0.50<br>2.90<br>14 | 0.50<br>2.80<br>13 | 0.30<br>0.70<br>4  | 0.70<br>4.20<br>14 | 0.40<br>2.10<br>10 | 0.40<br>2.70<br>13 |                    |                    |                    |                      |
| SNOTEL-05j41s            | 0.40<br>2.80<br>13 | 0.30<br>1.70<br>10 | 0.60<br>3.60<br>16 | 0.50<br>2.20<br>13 | 0.50<br>1.70<br>10 | 0.10<br>0.30<br>3  | 1.20<br>2.90<br>6  | 0.30<br>1.40<br>10 | 0.70<br>2.30<br>11 |                    |                    |                    |                      |
| SNOTEL-05j42s            | 0.50<br>2.20<br>14 | 0.40<br>1.90<br>15 | 0.60<br>3.50<br>18 | 0.50<br>1.90<br>10 | 0.20<br>1.60<br>12 | 0.20<br>0.40<br>3  | 1.90<br>4.90<br>10 | 0.50<br>1.20<br>5  | 0.70<br>2.50<br>11 |                    |                    |                    |                      |
| SNOTEL-05k06s            | 0.40<br>2.10<br>14 | 0.10<br>1.40<br>14 | 0.30<br>2.40<br>14 | 0.50<br>1.50<br>9  | 0.50<br>1.50<br>7  | 0.20<br>0.20<br>1  | 0.30<br>2.10<br>11 | 0.40<br>1.00<br>6  | 0.40<br>1.80<br>8  |                    |                    |                    |                      |
| SNOTEL-06j05s            | 0.20<br>1.90<br>16 | 0.30<br>1.50<br>10 | 0.40<br>2.20<br>15 | 0.60<br>1.50<br>10 | 0.40<br>1.10<br>7  | 0.20<br>0.40<br>3  | 0.60<br>2.10<br>11 | 0.30<br>1.00<br>5  | 0.50<br>2.70<br>13 |                    |                    |                    |                      |

**Table A.4. Maximum 24-Hour (blue), Total Accumulated (black), and Number of Precipitation Days (green) by Month, 2006. Precipitation is measured in inches.**

## 6.2. Appendix B: Supplementary Figures

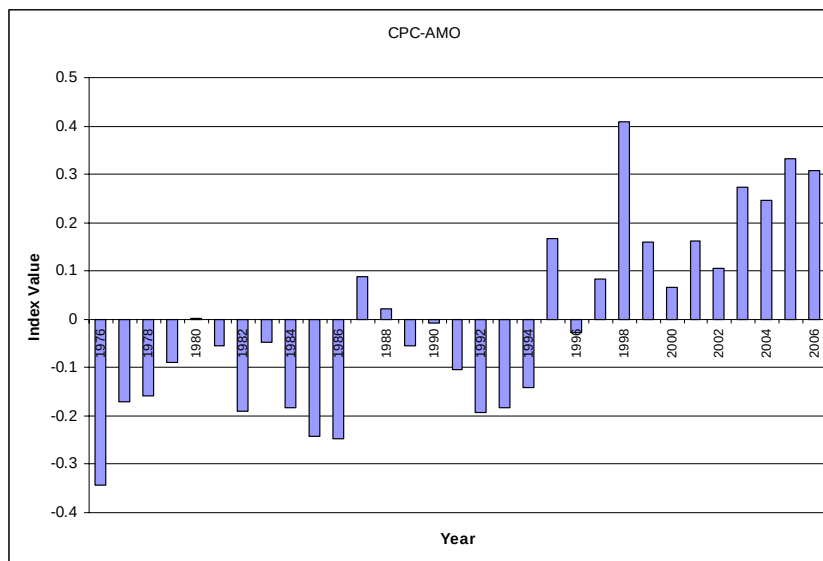


Figure B.1. Atlantic Multi-Decadal Oscillation (AMO) Index, 2000-2006.

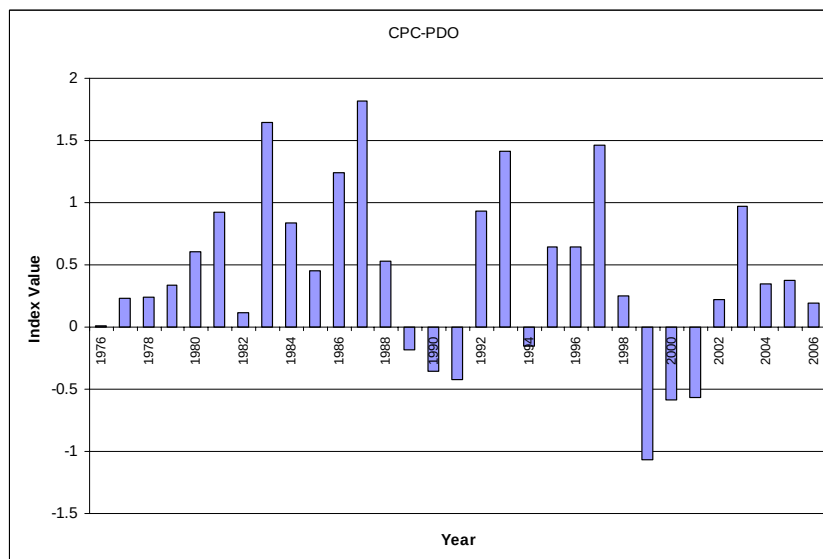


Figure B.2. Pacific Multi-Decadal Oscillation (PDO) Index, 2000-2006.

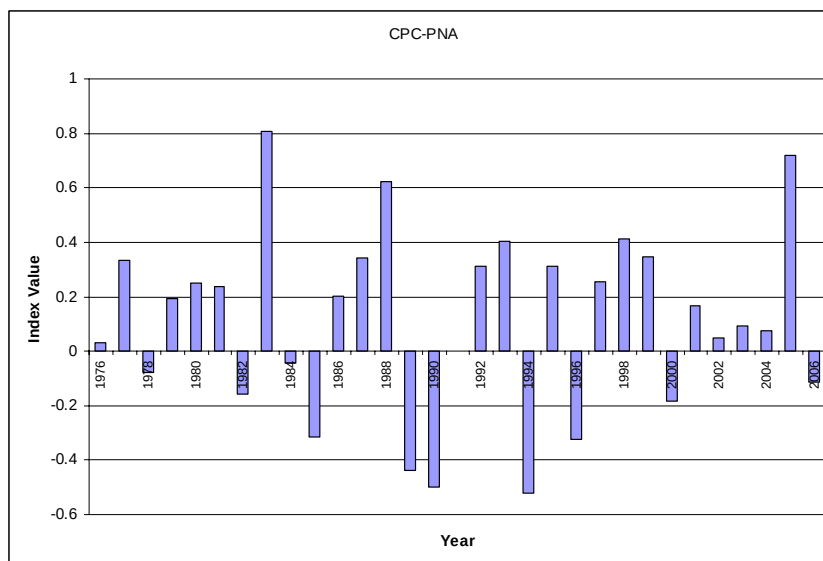


**Figure B.3. Pacific North American (PNA) Index, 2000-2006.**

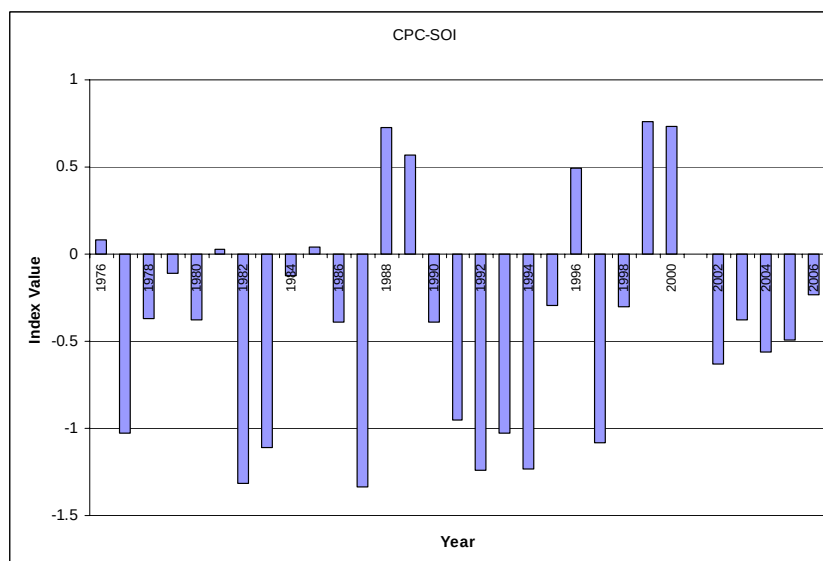


**Figure B.4. Southern Oscillation Index, 2000-2006.**