The following document was prepared by Dr. Russell Qualls in response to the numerous questions and comments provided during the January 2006 open houses for the U.S. 95 Thorncreek Road to Moscow Project.

So many comments and questions were asked of Qualls, that it was decided to provide him with his own section of the project Web page Q&A's. Questions and answers about other environmental studies conducted for the project are located on a separate link.

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Response to Public Comments on the Climate Study

Comments submitted are bulleted, followed by responses in italics. After some specific responses to individual questions, there are several sections that address the questions more comprehensively. The latter includes the following sections:

Wind Comparison
Temperature Lapse Rate
Snow Distribution in the Study Area
Historical Representativeness of 2005 Measurement Period
  Snow
  Air Temperature
  Precipitation
References Cited

- Abnormally warm temperatures reduce the amount of fog present in areas where E1 and E3 would be located

Response: The abnormally warm temperatures may have reduced the amount of fog present during the study period, however, it should not have preferentially affected only the E1 and E3 alternative alignments; it should have affected all alignments, in which case the 2005 measurements would still provide representative information about the relative behavior of the three measurement sites with respect to fog. Nevertheless, it is important to note that the most significant fog was measured in the southern third of the study area at the Reisenauer Hill measurement station. This station is representative of all alternatives, since every possible alternative must pass above the 2,900-foot elevation in traversing the southern portion of the study area.

- Eastern alignments will have more fog and snow

Response: to the degree that this is true, it is reflected in the report, and in the set of responses to public comments. However, it is important to note that the most significant fog was measured in the southern third of the study area at the Reisenauer Hill measurement station. This station is representative of all alternatives, since every *possible alternative must pass above the 2,900-foot elevation in traversing the southern portion of the study area.*

- Paradise Ridge is windier, foggier and has more snowfall than surrounding areas

Response: Wind. As shown in the analysis of wind in the accompanying response (See section: "Wind Comparison"), and in the following table, the wind speeds at the Eastern Corridor (EC) measurement station were significantly slower than at Reisenauer Hill (to which all alternatives are exposed) for any wind speed over 10 mph, and slightly lower than the Western Corridor (WC) wind speed measurements.

Wind Table	*HFA-RH*	*HFO-EC*	*LFO-WC*
Fastest Individual Gust (mph)	*57.0*	*44.1*	*47.4*
Fastest Individual 5-minute Average (mph)	*49.0*	*35.1*	*40.0*
Average of 5-minute Gusts (mph)	*13.8*	*11.5*	*9.8*
Average Wind Speed (mph)	*11.6*	*8.4*	*7.6*

Most importantly, it is for the highest wind speeds that the EC exhibits milder conditions than RH or WC, as shown in the following upper-tail wind gust speed histogram, taken from the "Wind Comparison" prepared in response to the public comments.

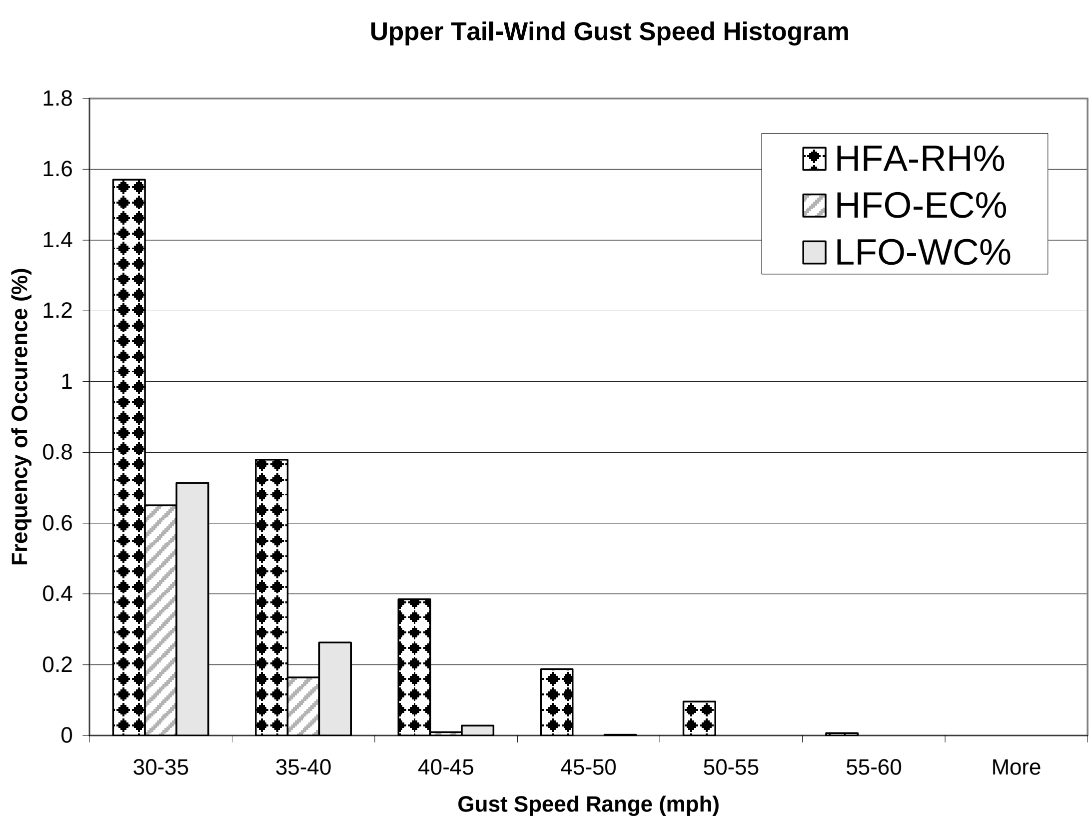

Figure 2. Histogram of the upper-tail of wind gust speeds, for gusts in excess of 30 mph.

Response: Fog. To the degree that the EC was foggier than the WC, this is reflected in the report, and in the set of responses to public comments. However, it is important to note that the most significant fog was measured in the southern third of the study area at the Reisenauer Hill measurement station. This station is representative of all alternatives, since every possible alternative must pass above the 2,900-foot elevation in traversing the southern portion of the study area. Therefore, all possible alternatives will be exposed to the most significant fog that occurs in the study area since they all must traverse the southern one-third of the study area.

Response: Snow. The depth of snow in a location is determined by the balance of past deposition and melting. Deposition of snow depends on depth of precipitation at a given location, and a sufficiently cold temperature to cause the precipitation to fall as snow rather than rain. In high topographic relief areas, including the Moscow, Idaho area, the depth of precipation tends to increase with elevation, and the temperature tends to decrease. In fact, the increase of precipitation is largely governed by the altitudinal decrease of temperature, which causes increased condensation and cloud formation in air masses, and hence more precipitation at higher elevations than at lower. Over large elevation differences, such as between the City of Moscow (2,600 feet), and the top of Moscow Mountain (4,983 feet), which differ by nearly 2,400 feet of elevation, this difference is significant. As noted in the section of "Temperature Lapse Rates", the temperature differences based on the saturated or dry adiabatic lapse rates between the City of Moscow and Moscow Mountain are 7.9 °F to 14.4 °F, respectively. Based on snow measurements at the Moscow Mountain SNOTEL site, this is sufficient so that at the time of this writing (March 29, 2006), there is 56.4 inches of snow on the ground or 21.6 inches of snow water equivalent near the top of Moscow Mountain, and a temperature difference between Moscow Mountain and the UI Plant Sciences Farm of 9.1 °F.

Although the Climate study reported a precipitation difference between the Eastern Corridor and the Western Corridor, presumably due to the elevation difference, and the close proximity of the plateau of the EC site to Paradise Ridge, the temperature differences are not sufficiently large to sustain long-lasting differences in accumulated snow between the EC and WC sites. Certainly there are times when it snows on the EC plateau, but does not snow in the City of Moscow, or at the WC site, and sometimes the snow persists on the EC Plateau when it does not at lower elevations. As noted earlier, the small difference between the temperatures at EC and WC and the infrequency with which WC and EC reside on opposite sides of the required temperature to allow snow at the upper site and rain at the lower reduces the frequency at which this might be expected to occur. In order to get a good idea of the frequency of persistent snow at EC when there is none at WC, one must consider the causes of snowmelt.

Melting, or snow ablation, is primarily caused by a flux of energy into the snow pack. There are three primary sources of energy for snow melt: solar irradiance from *sunshine, heat released by the condensation of water vapor onto the snow surface, and heat absorbed from warm winds blowing over the snow also known as convection (Linacre, 1992). The relative influence of each of these terms in the study area are discussed in detail in the section "Snow Distribution in Study Area". The conclusion is that the variable which exhibits the most significant variability across the study area is absorption of solar radiation as a function of land slope and aspect (i.e., the compass orientation of the slope). This results in persistence of snow on north-facing slopes, which gives the appearance from Moscow that snow persists on Paradise Ridge when it has dissipated from lower elevations, but is more a factor of what can be seen from Moscow. In short, all alternatives must come down a north-facing slope from an elevation of approximately 2,900 feet to approximately 2,600 feet in order to come into Moscow, and are thus similarly exposed to snowy conditions. This is discussed in greater detail in the section on "Snow Distribution in Study Area" in the responses to the public comments on the climate study.*

- Should have conducted weather study for each route

Response: At the time the study was initiated, none of the specific alternatives had yet been laid out, to my knowledge. In designing the study, I used a common climatological study design practice which is to stratify a region into significant different characteristic areas (or the extremes across a gradient) and sample representative areas. The characteristics deemed important to analyze for this study were elevation, and whether the dominant east-west air movement had to flow up and over Paradise Ridge after leaving the study area, or whether it moved around the south end of the study area. Stratification by these characteristics resulted in three climate regimes for this study: Highland Flow-Over (HFO), Highland Flow-Around (HFA), and Lowland Flow-Over (LFO). These regions are shown on the study area map appended to the climate report and defined in that report. Even if the alternatives had been defined prior to the planning stages of this study, none of the alternatives occupy what can be classified as a single, unique climate regime, nor is it possible to design an alternative which does so because of the changes which occur across the study area in the North-South direction, that is, longitudinally along each of the proposed alternatives. Instead, based on the criteria used to define the climate regimes within the study area, each alternative could be described by a combination of either two or all of the regimes. In the case of the central alternative routes, C-3 was a combination of the HFA and HFO regimes, and C-2 and C-1 were a combination of the LFO and HFA regimes, with a small contribution from HFO. Similarly, routes E-1, E-2 and E-3 traverse combinations of climate regimes HFO and HFA, whereas W-1, W-2, W-3, and W-4 traverse combinations of LFO and HFA, and a small portion of HFO. In the end, the differences between C-1 and C-2 compared to the western routes was sufficiently small to group them together. There was a similar result for the relationship of route C-3 with the eastern routes. In general, the ten different alternatives were not proposed because it was believed that each represented a distinct climate within the study area, but rather they were proposed to evaluate the merits of a number of alternatives with respect to a *broad range of criteria. Some of these criteria, such as wetland area disturbed, or number of existing structures impacted, allowed distinction between each and every alternative; climate is not a criteria that can be as finely divided.*

- Doubt accuracy of climate data; weather station should have been farther north

Response: There were three stations within the study area, one on Reisenauer Hill, one in the Eastern Corridor, and one in the Western Corridor (see study area map in Climate Report for locations). All three stations were located so as to measure particular climate effects within the study area, including low-versus high elevation, and air flow over versus flow around Paradise Ridge. Moving them would have reduced their ability to capture the differences between the influential factors of elevation and air movement over the ridge.

- This analysis is incomplete and invalid for choice of safe route alternatives

Response: Substantially more analysis has been included in the responses to the public comments, which was prompted by the many valuable questions that were asked.

- Value for road ice conditions should not be included in the matrix until more complete, long-term, and valid data are collected

Response: It would not be appropriate to exclude one variable (road ice), which more adversely affect the Western Corridor than the Eastern Corridor, and retain other variables.

- Exhaust from vehicles and dissipation was not considered and will increase fog, ice and wetness over time

Response: In many major cities, there is sufficient automobile traffic to generate measurable and observable air pollution from vehicle emissions. In these highly urbanized areas with poor air quality, there may be the potential for vehicle emissions to interact with moisture in the air to generate fog. The Moscow area does not appear to produce sufficiently high emissions for air quality to be a problem, apart from dust and smoke which are not associated with vehicle emissions. If at some point in the future vehicle emissions reach the level that they begin to influence fog, etc., it will not be a localized phenomenon that would appear on one roadway alternative only, but due to turbulent mixing in the atmosphere, it would affect the entire greater Moscow area, including all possible alternatives of the Thorncreek Road to Moscow Highway Realignment Project.

- There should be weather studies done for the central routes as well as for the east and west. It is hard to make comparisons when there are no data from each of the regions.

Response: At the time the study was initiated, none of the specific alternatives had yet been laid out, to my knowledge. In designing the study, I used a common climatological study design practice which is to stratify a region into significant different *characteristic areas (or the extremes across a gradient) and sample representative areas. The characteristics deemed important to analyze for this study were elevation, and whether the dominant east-west air movement had to flow up and over Paradise Ridge after leaving the study area, or whether it moved around the south end of the study area. Stratification by these characteristics resulted in three climate regimes for this study: Highland Flow-Over (HFO), Highland Flow-Around (HFA), and Lowland Flow-Over (LFO). These regions are shown on the study area map appended to the climate report and defined in that report. Even if the alternatives had been defined prior to the planning stages of this study, none of the alternatives occupy what can be classified as a single, unique climate regime, nor is it possible to design an alternative which does so because of the changes which occur across the study area in the North-South direction, that is, longitudinally along each of the proposed alternatives. Instead, based on the criteria used to define the climate regimes within the study area, each alternative could be described by a combination of either two or all of the regimes. In the case of the central alternative routes, C-3 was a combination of the HFA and HFO regimes, and C-2 and C-1 were a combination of the LFO and HFA regimes, with a small contribution from HFO. Similarly, routes E-1, E-2 and E-3 traverse combinations of climate regimes HFO and HFA, whereas W-1, W-2, W-3, and W-4 traverse combinations of LFO and HFA, and a small portion of HFO. In the end, the differences between C-1 and C-2 compared to the western routes was sufficiently small to group them together. There was a similar result for the relationship of route C-3 with the eastern routes. In general, the ten different alternatives were not proposed because it was believed that each represented a distinct climate within the study area, but rather they were proposed to evaluate the merits of a number of alternatives with respect to a broad range of criteria. Some of these criteria, such as wetland area disturbed, or number of existing structures impacted, allowed distinction between each and every alternative; climate is not a criteria that can be as finely divided.*

- Weather data's is prospective and nicely designed but unfortunately is based on 2 of the mildest winters the Palouse has ever seen. The data's complete representation of the area over years is uncertain.

Response: Please see the detailed analysis of the Representativeness of the 2005 Measurement Period with respect to the historical climate of the region which is presented later in the response to these comments. Some aspects and/or portions of the winter were mild, others were not. It is important to note that the purpose of the study was not to establish a climatological average or extremes for each of the measurement sites (although there is a way to do that based on comparison to the nearby Plant Sciences Farm long-term record), but rather to quantify the relative differences between the climate regimes of the study area. Many of these differences are driven by well-understood thermodynamic principles that behave the same regardless of the conditions of one particular year relative to the climatological norm.
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- I am concerned that the climate study was done during a period of abnormal warmth. I see Paradise Ridge daily—it is frequently covered in clouds, including the areas in which E-1 to E-3 are located. I think the fog data was skewed by a warmer-than-normal year and that these roads will be much more dangerous than anticipated.

Response: Please see above, and the detailed analysis of the Representativeness of the 2005 Measurement Period with respect to the historical climate of the region, which is presented later in this response. In addition, please note that all alternative routes pass through the southern "HFA" area and all must exceed 2900 feet elevation while doing so. When fog was present, it was consistently most dense in the southern HFA area, and thus affects every possible alternative.

The climate analysis is not convincing, of the ten different alternatives, there are only two values for fog (49 & 69 hours) and two values for road ice (128 or 158 hours). This would indicate that there was not sufficient data to do a site-specific analysis sufficient to compare the different alternatives. Thus, no conclusions can be drawn. This is what any peer reviewer of this data would conclude.

Response: There were far more than four data values measured during the study. Much of this data is discussed at length in the climate report, which ITD distributed on CD at the January open house. The numbers presented on ITD's comparison matrix reflect the fact that the climate study was not designed to uniquely describe each route within a set of alternative routes, but to stratify the study area according to the dominant characteristics which were likely to produce climate differences across the study area. Please see the description of the how the stratification was implemented, above. Using this stratification method allowed climate considerations to drive the study design, rather than transportation considerations, and is what peer reviewers of a scientific study would expect.

(1) Thus we must fall back on anecdotal evidence. I walk my dog every morning on the Paradise Creek path with a clear view of Moscow Mountain. In the winter, at least 30-50 mornings it is not frozen on Paradise Creek path, but one can see the fresh snow line on Moscow Mountain, where the previous nights rain/dew in the valley was snow/frost at the higher elevations part way up Moscow Mtn. This snow line is commonly close to the base of the mountain, approximately 2600-3000 feet in elevation.

Response: see comments after (2) below.

(2) I have often driven my car over Moscow Mtn on steakhouse grade in the winter and often have noticed that although the road is wet at the bottom of the grade,

it becomes frozen (& slippery) at some point up the grade I assume this point corresponds roughly to the snow line in the #1 above.
The above two observations are common knowledge in Moscow; countless others I know have made the same observations. Extrapolating these observations to the other geographical protuberance in the area, Paradise Ridge, one would conclude that the Eastern routes (which are highest) would have a certain number of mornings on which they would be frozen, but the lower (C & W) routes would just be wet. (IT COMMONLY RAINS AT THE LOWER VALLEY ELEVATIONS WHEN IT SNOWS UP HIGHER—THIS IS COMMON KNOWLEDGE, BUT THIS IS NOT REFLECTED IN THE CLIMATE ANALYSIS!)

Response to (1) and (2) above: While anecdotal evidence is useful if properly quantified, I strongly disagree that there is nothing more useful than anecdotal evidence to fall back upon. The climate study provides simultaneous measurements at key locations within the study area. These measurements, using identical instruments and protocols at all the sites, are the only source for quantitative comparison among the different climate regimes of the study area. For example, when the eastern corridor (EC) measurement was colder than the western corridor (WC) measurement, which it was three-fifths of the time from January through May 2005, the average difference was 1.8 °F, and the largest difference observed was 6.5 °F. Over the five months from January through May 2005, there was a cumulative total of 1 hour during which EC was colder than WC by more than 5°F. Differences this small are difficult to detect by casual observation, and it is impossible to determine the frequency without regular ongoing measurements. Incidentally, the temperatures at WC were colder than those at EC two-fifths of the time, and when WC was colder, the average difference was 5.4°F, and the maximum was 27.4°F. WC was more than 5°F colder than EC for more than 525 hours between January and May. Of course the circumstance in which a temperature difference between the two sites becomes important is when one of the two sites is above freezing, and the other is below freezing, since this is when conditions could be deemed better, from a driving perspective, in one climate regime of the study area than the other. During the five month study period, EC was below freezing while simultaneously WC was above freezing, for only 71 hours. On the other hand, WC was below freezing while simultaneously EC was above freezing for more than 226 hours; the low elevation WC site was below freezing while the higher elevation EC site was above freezing for more than three times as many hours as the reverse condition. Some of these hours occurred during the high pressure system that sat over the Pacific Northwest from mid-February through mid-March, but many occurred outside this time period. There is a very specific thermodynamic reason why there are more hours at the lower site than at the upper site satisfying this condition, which I discuss in a later section (see section on Temperature Lapse Rate). One of the things that these observations point out is that anecdotal evidence tends to emphasize things that are within sight; since neither the low elevation nor high elevation areas of the western corridor or southern region are visible from Moscow, owing to the presence of Clyde Hill, events there tend to remain unobserved. The issue of snow at higher elevations is *addressed later, since several questions arose about it. Please see the section on "Snow Distribution in Study Area".*

- Weather conditions for the eastern routes would be more valid if the measurements were taken at points on the proposed routes—i.e. walk out into fields to do measurements.

Response: The eastern corridor station (EC) was located out in the field, within the right-of-way of proposed route E-2, and near the easternmost boundary of the study area. See "EC RWIS Site" on the Study Area Map in Appendix B of the Climate Report, or triangle symbol labeled "RWIS Site" located approximately midway along alternative E-2 on ITD's Eastern Alignment Map. However, the placement of the stations was not intended to measure the conditions on any specific alternative, but rather to capture the conditions at the extremes of each of three different climate regimes. These included the "Highland, Flow-Over" area, corresponding to the central portion of the Eastern Corridor and the Eastern-Central part of the Central Corridor, the "Lowland Flow-Over" area, corresponding to the lowest area in the of the Western Corridor and the Western half of the Central Corridor, and the "Highland Flow-Around" area through which all alternative roadways traverse across the southern one-third of the study area. In the preceding description, "Flow-Over" and "Flow-Around" refer to the dominant pattern of weather either flowing up and over, or around the south end of Paradise Ridge, respectively.

- One year's data is almost meaningless on the Palouse and the 1-year of the study was an extreme year for temperature and snowfall.

Response: If the study was attempting to establish the complete, absolute climate of the study area or even of the individual measurement sites in the absence of other longer term measurements, this comment would be absolutely correct. However, the climate study focused on determining the relative differences of several climatological variables between sites. Many of these differences related to physical and/or thermodynamic properties, as does the temperature lapse rate with elevation, which maintain similar relative characteristics regardless of the actual magnitude of the specific variable. Please see the discussions of the "Wind Comparison", "Temperature Lapse Rate," and "Snow Distribution in Study Area" for discussion of these characterists. Please see "Historical Representativeness of 2005 Measurement Period" below.

- The inversion mentioned is not typical in winter, ONLY in summer. This winter's snow pattern is more typical with snow as you go up in elevation and bare ground at the lower elevations. This is classic case of vertical difference.

Response: It is important to distinguish between a stationary high pressure system, and cold air drainage. Although the persistent high pressure system that occurred last *year and lead to a clear weather and a dry February may be infrequent during Winter on the Palouse, cold air drainage is very common, and regularly leads to colder nighttime temperatures in the lower valleys compared to the highlands. It is occurring frequently again this year, and occurs on clear nights, cloudy nights, nights with precipitation, etc. It is not an infrequent or isolated phenomenon. Regarding snow, the most significant snow event of the winter blanketed and remained over the entire Palouse in excess of three weeks. However, the snow which occurred around the time of the open house, despite appearances, also occurred in Moscow. Plant Sciences Farm just outside of town and located at 2600 feet of elevation recorded new snowfall, in sufficient quantity to be accumulated on the ground, on January 1, 8, 9, 14, 16, 17, 18, 19, 20, 21, 22, 27, 28, 29, and 30. What one observes from Moscow looking south toward Paradise Ridge or the plateau of the eastern corridor is significantly affected by the slope and northern aspect (directional orientation) and its affect on the radiation distribution for snowmelt purposes. For more comprehensive discussion on this, please see the discussion of "Temperature Lapse Rate" and "Snow Distribution in Study Area", later.*

- The climate study is not valid! One year is not an appropriate length of time for such a study. In addition the year of the study was the warmest and most atypical in the 27 years we have lived here. To further this anomaly, the inversion, which occurred last winter, caused opposite data regarding temperatures. In winter, temperatures are lower as you rise in elevation. We saw this demonstrated this week with the snow. The summertime inversion is normal, but an inversion like experienced in winter 2005 is not normal! However, the data stating the Western routes were colder in winter caused a faulty conclusion that all sites were equal regarding climatic conditions and no alignment should be eliminated because of microclimate severity.

Response: If the study was attempting to establish the complete, absolute climate of the study area or even of the individual measurement sites in the absence of other longer term measurements, this comment would be absolutely correct. However, the climate study focused on determining the relative differences of several climatological variables between sites. Many of these differences related to physical and/or thermodynamic properties, as does the temperature lapse rate with elevation, which maintain similar relative characteristics regardless of the actual magnitude of the specific variable. Regarding the cold temperatures in the western corridor, it is important to distinguish between a stationary high pressure system, and cold air drainage. Although the persistent high pressure system that occurred last year and lead to a clear weather and a dry February may be infrequent during Winter on the Palouse, cold air drainage is very common, and regularly leads to colder nighttime temperatures in the lower valleys compared to the highlands. It is occurring frequently again this year, and occurs on clear nights, cloudy nights, nights with precipitation, etc. It is not an infrequent or isolated phenomenon. Please see the discussions of the "Wind Comparison", "Temperature Lapse Rate," and "Snow Distribution in Study Area" *for discussion of these characterists. In addition, please see "Historical Representativeness of 2005 Measurement Period" below.*

- **Weather Analysis report:** The findings of the Weather Analysis should indicate that the timing and seasonality of differences in both moisture and temperature between higher elevation and lower elevation sites are critical. Variations in temperature in the context of season and elevation require specification, in that it is often significantly cooler in lower elevations during warmer seasons (e.g., low-lying frost pockets in the fall) that pose less danger for highway travel, and significantly colder conditions in higher elevations during the winter that pose much greater threats for safe highway travel. As noted above, the worst cases, and duration of these, in terms of undesirable weather conditions – not just averages – need to be provided, which would document that the E routes have more snow and ice. Significantly for highway safety, anyone living in Moscow, including Dr. Qualls, has looked up at Paradise Ridge and observed that it is clear or only raining in Moscow at the same time that it is snowing or icy on the Ridge (this phenomenon occurred just days before the ITD meeting – on Jan. 16 and 17, 2006 -- when the ridge was covered in a sheet of ice, and the next day snowfall, while other locations to the north and west were not).

Response: Now two months later, I don't recall from memory what the 16th and 17th of January brought, but when I look at the recorded data, Plant Sciences Farm just outside of town and located at 2600 feet of elevation recorded new snowfall, in sufficient quantity to be accumulated on the ground, on January 1, 8, 9, 14, 16, 17, 18, 19, 20, 21, 22, 27, 28, 29, and 30. One of the reasons I believed the measurements of this study were important was that anecdotal evidence frequently does not do a good job of integrating accurately over space or time. The Climate Report does address the worst case scenarios, namely, the cumulative hours with temperatures below freezing, and simultaneously relative humidity values at or near saturation, corresponding to periods of rain, snow, or heavy dew, which is likely to freeze. Regarding the temperature lapse rate, and snow at higher elevations, please see discussion of these topics later.

- Precision versus accuracy. I have no doubt that the data for climate was collected precisely, but I believe, in terms of long term accuracy, it is flawed. That extremely short collection interval that encompassed an aberrant winter makes some of the conclusions dubious. It's common knowledge that cold air flows downhill, so I'm not surprised that the WC showed precipitous change in air temperature. Unfortunately, because of the abundance of clear weather (no precipitation events) last winter/spring, and because clear skies promote radiant cooling, the occurrence of such events was no doubt more frequent than if a more typical weather pattern with more precipitation and less radiant cooling had been in place. This should reduce the number of hours of “road ice” conditions. That results in goofy statements like: The importance of the similarity in number of hours of freezing temperatures in January among three sites is that it illustrates that during stormy winter conditions, one can expect similar durations of freezing temperatures across the study area. The state climatologist should drive from Moscow to my home during each winter event to see the lunacy of that statement. Just days before the open house we had the more typical event: rain along US 95 from the Eid Road intersection to Moscow; several inches of snow at my house. Snow persists longer at higher elevations.

Response: The study period was not uniformly warm nor dry, although there certainly were periods (especially February into the early part of March) that were warm during the day and dry. In contrast, March and May were extremely wet months, and April was close to the median value. This is discussed in detail in the section “Historical Representativeness of 2005 Measurement Period” below. There were a number of factors for which the range of observations that occurred actually benefited the study compared to what would have happened if the weather had fallen exactly at the median each month.

For example, the wide range of observations with respect to climatological normals, made the 2005 study period nearly perfect for what we hoped to accomplish with respect to precipitation. There were two goals: one was to establish the relative magnitudes of monthly precipitation between the three stations in the study area; the other was to establish the climatological norm for each station with respect to the long term record at the UI Plant Sciences Farm. With regard to the relative magnitudes of precipitation within the study area, the different months brought a wide range of precipitation, yet the stations maintained their same relative magnitudes. This provides a high degree of confidence that the relative magnitudes of precipitation as measured during the study period will be maintained regardless of how large the precipitation depth is during a given month. Secondly, the wide range of monthly precipitation depths observed allowed us to assess the relationship of the precipitation at each of the study sites to that at the UI Plant Sciences Farm. Had all the values fallen at or near their median values, the tight cluster of points would have made it impossible to extrapolate outside that range with any certainty. As it was, between January and May, 2005, values of monthly precipitation between 0.32 inches and 4.00 inches were observed at the UI Plant Sciences Farm (PSF), and there was a strong correlation between the PSF values and those in the study area, as shown in Figure 34 below, which is a reproduction of Figure 10 from the Climate Study. This gives great confidence in the relationships established between monthly precipitation at PSF and the three measurements stations in the study region, which further allows us to estimate the climatological normal values for monthly precipitation at the individual stations based on the long term record at PSF with greater confidence.

With regard to the effect of the clear period in February and early March, the associated radiant cooling did not increase the frequency of cold air drainage, only the magnitude of the difference. Throughout the rest of the study period, and in spot checks this year, cold air drainage continues to occur regularly. Under cloudy conditions, the drop is often on the order of 5-10 °F rather than 15°F as observed under clear sky conditions. However, this still creates much more opportunity for the low-lying areas such as found in the western corridor to reside in freezing temperatures when the upper portion of the study area (eastern corridor) is above freezing (see figure 6 below and the associated discussion on temperature lapse rates). Furthermore, as discussed in the Temperature Lapse Rate section, the study confirmed that there is an almost impermeable upper limit to how much warmer WC can be compared to EC on a sustained basis, owing to the thermodynamics of atmospheric stability, and that difference is only about 2.2°F. Regardless of whether a year is warm or cold, wet or dry, this limit will be in place. The only thing that could change this would be a substantial change in gravity. Conversely, WC can and frequently does get much colder than EC. The net effect of the limitations imposed by the adiabatic lapse rate (preventing EC from getting much more than about 2.2 °F colder than WC over extended periods), and cold air drainage (allowing WC to get much colder than EC) is still to allow freezing conditions to be more prevalent in the WC than in EC. This is not likely to produce more snow at WC, but it does have the potential to generate more frequent road ice.

Regarding persistence of snow at higher elevations, there is not a sufficiently large elevation difference across the study area to regularly make a significant impact in this regard. The perceived elevation effect is predominantly caused by radiation exposure as a function of land slope and aspect, or shading effects. This is discussed in detail in the section, "Snow Distribution in Study Area," below. Also, note the Plant Sciences Farm just outside of town and located at 2600 feet of elevation recorded new snowfall, in sufficient quantity to be accumulated on the ground, on January 1, 8, 9, 14, 16, 17, 18, 19, 20, 21, 22, 27, 28, 29, and 30.

- An understanding of long-term trends for "typical" weather on the different routes needs to be accurately documented in this report, and incorporated in the Safety Analysis as well; as it is, this report does not adequately assess the indirect impacts of weather for highway maintenance, snow removal, policing, and the like. The Weather Analysis also is incomplete in the context of cumulative effects: this past year was an abnormally dry and hot year, and any analysis of weather needs to take a longer-term perspective, as the Weather Analysis report recognizes but does not accomplish. Major variations in conditions on a ridge route (Alt. E) would result in people driving too fast for conditions, resulting in higher accident rates and thus less safety. As it is, this analysis is incomplete and invalid for choice of safe route alternatives. Further, the differences just noted above need to be accounted for in the Safety Analysis.

Response: The long term typical weather for the different climate regimes in the study area can be determined by analyzing the study period measurements with the long term measurements at the University of Idaho Plant Sciences Farm, which is presented in the section "Historical Representativeness of 2005 Measurement Period" below. However, the important question is not what is the long term weather at various points in the study area, but rather what are the DIFFERENCES between different parts of the study area. It is these differences that the climate study was designed to evaluate, and which can be done with a much shorter study than would be required to establish the climatological norm independent of the PSF data, at points within the study area.
As far as impacts of weather on highway maintenance, snow removal, policing, etc., those were not explicitly included in the mandate for this study, but you do raise a good question that I would like to address. Consider snow removal. If there is heavy snowfall, say 3 inches in the low elevations, and 4 inches at the higher elevations, all routes must be plowed; the shorter the route the less time and fuel must be devoted to plowing the segments of road in the study area. If snow only falls at the higher elevations, say 2900 feet and above, then there would be snow on E-1, E-2, and E-3 on the plateau below Paradise Ridge, and on routes E-1, E-2, E-3, C-1, C-2, C-3, W-1, W-2, W-3, and W-4, that is, on all the routes, in the southern portion of the study area in the vicinity of Reisenauer Hill. There is currently a snowplow turnaround at the intersection of Thorncreek road and U.S. 95. County snowplows are dispatched from West Palouse River Drive. From there, a plow will work its way south, past Reisenauer Hill to Thorncreek Road, turn around, and plow the northbound lanes on the return trip. Under this scenario, there would be a greater distance of plow engagement on the Eastern alternatives, but greater total driving distance on the routes with longer overall road lengths, which increase for alternatives further west. With regard to policing, I suspect shorter routes would provide faster access time to events in the south.
With regard to how the 2005 measurement period compared to the historical climate of the region, see section on "Historical Representativeness of 2005 Measurement Period" below. Certainly parts of last year were warm and dry, but there were also cold periods. January, for example had 16 consecutive days during which the daily minimum temperature did not rise above 24 °F, including 5 days between 10 and 19 °F, and one day down to 2 °F. During the past 35 years, 40% of the years had less cumulative snowfall than occurred in January 2005. The average daily minimum temperature in January was in the middle third of all years in the past 35 years, and the average daily minimum temperatures for February, March and April were all colder than at least half of the last 35 years. In the case of March, 29 of 35 years had a warmer average daily minimum temperature. More details appear below.

- E1, E2, E3, C3 found to have 30% more precipitation than Ws, C1, C2 (p.25). Therefore more snow on the Eastern Alignments.

Response: It is worse to drive through or plow 3 feet of snow than 3 inches of snow, but is it worse to drive through or plow 3.9 inches than 3 inches? I don't believe the differences are significant enough to become a primary determinant in alternative *selection, especially since there are other factors that are worse in the western corridor than in the eastern corridor.*

- E1, E2, E3, C3 have more fog than Ws, C1, C2 (p. 25, 26). Worst cases (and amount of time in bad conditions), not averages, are important.

Response: The worst cases of fog occurred in the southern highland flow-around portion of the study area, which every possible alternative must traverse.

- What about the effect of wind on snow?

Response: melting and redistribution.

- Interview knowledgeable folks: road maintenance people, residents.

Response: This was partially the intent of the open house and the monthly breakfast meetings. The comments received from the open house in particular were the impetus for the present analysis and document.

- Check damage reports (roofs blown off).

Response: As discussed in the Wind Comparison section below, continuous measurements show that wind speeds are within a few miles per hour of each other at the EC and WC sites (slightly higher at RH near where all alternatives pass), so this factor should not effect alternative selection.

- What are this winter's snows showing?

Response: November 3.57 inches, December 7.2 inches, January 4.0 inches, and February 2.0 inches. Despite the number of observations of how much more severe this winter has been compared to the winter of the study period, none of this winter's cumulative snowfall depths beat the study period's January snowfall of 7.9 inches.

- Wind was not actually measured on sight. There are 80+ mile an hour winds that I have measured for the past 6 years on E2. C2 was not even considered. Trucks will have big trouble on E2.

Response: Wind Comparison.

Wind was measured at all three stations, whose locations are shown on the Study Area Map of the Climate Report, and on the ITD alignment maps. These included one station in each of the three climate regimes, Highland Flow Around (HFA-RH), Highland Flow Over (HFO-EC), and Lowland Flow Over (LFO-WC), as defined in the Climate Report. The protocol used for measurement of wind speed was to place the sensors at *the top of each tower, at 30 feet above ground level, to avoid interference of the tower structure itself on the measurements, and to ensure compatible measurements at each site. The results are shown in the following table and in Figures 1-5.*

Wind Table	*HFA-RH*	*HFO-EC*	*LFO-WC*
Fastest Individual Gust (mph)	*57.0*	*44.1*	*47.4*
Fastest Individual 5-minute Average (mph)	*49.0*	*35.1*	*40.0*
Average of 5-minute Gusts (mph)	*13.8*	*11.5*	*9.8*
Average Wind Speed (mph)	*11.6*	*8.4*	*7.6*

I cannot comment on the accuracy of the 80+ mph observations reported by the person who submitted this comment, other than to say that I would not be surprised if occasionally wind gusts of that magnitude had occurred on the Palouse. The wind data collected as part of this study does however contribute important information to this issue. If one looks at the table above there are some very important comparisons that can be made. The data were taken from the measurement period January through May, 2005. Since this is a limited time period, this data should not be interpreted as providing absolute long-term averages, or anticipated maximum winds. However, given the close proximity of all three sites, and the fact that wind storms are large scale phenomena, these data provide a very good spatial intercomparison among the three stations, and the major climate regimes of the study area (namely, Highland Flow Around (HFA-RH), Highland Flow Over (HFO-EC), and Lowland Flow Over (LFO-WC), as defined in the climate report. Since wind storms are large scale phenomena, relative to the size of the study area, the predominant factors that affect the relative speeds of winds observed in various parts of the study area are topographic features, and local roughness elements (e.g., clumps of trees serving as wind breaks).

To illustrate the relative magnitudes of the winds in the three climate regimes, I have prepared a series of figures from the data of the maximum gust observed during each 5 minute interval throughout the reporting period from January through May, 2005. These figures are comprised of 42593 data points at each measurement site. The data represent the fastest wind speed observed in each five-minute period, and therefore exceed the mean for each of the corresponding five-minute periods. Figure 1 presents a histogram of the percent of gusts whose speeds fell within a specific range of speeds, in 5 mph increments, at each of the three sites.

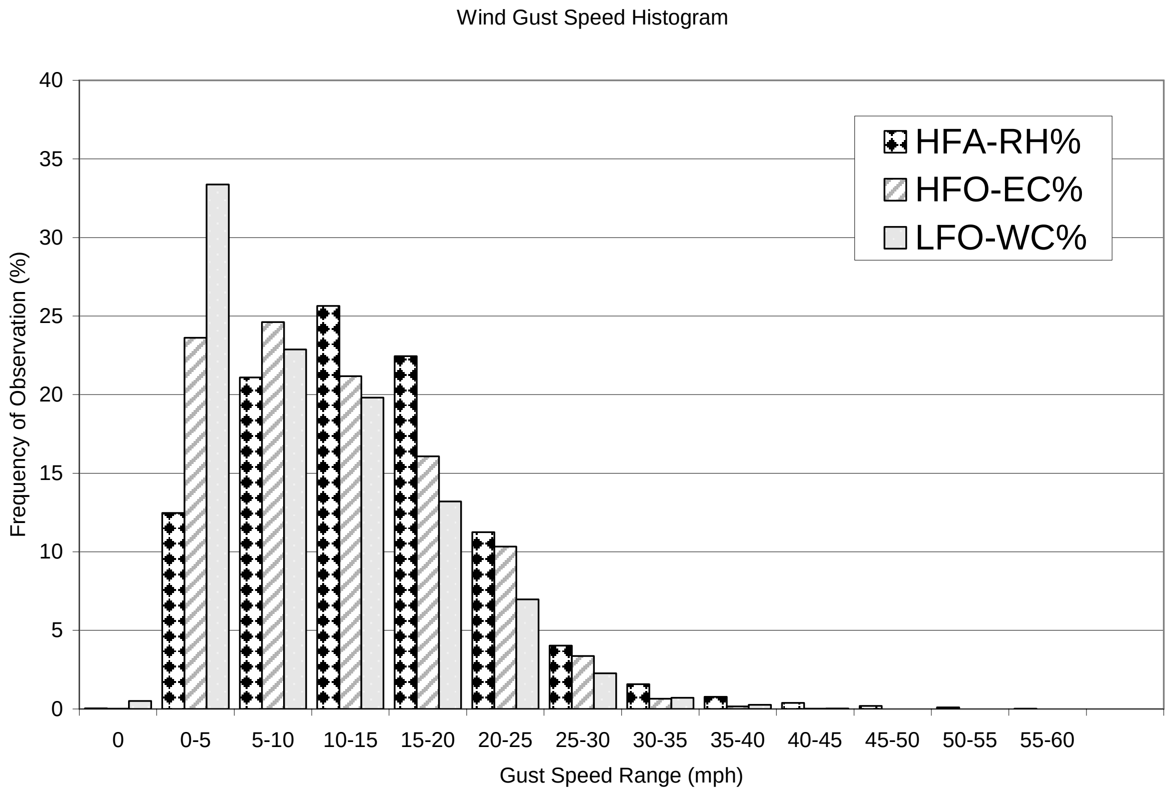

Figure 1. Histogram of wind gust speeds at the three measurement sites. The frequency of observation refers to the percentage of the five-minute intervals during the five months in which a gust within the specified range occurred.

As one would expect, by far the greatest percentage of gusts did not exceed 30 mph. Cumulatively, 99% or more of the gusts were slower than 30 mph at the EC and WC stations. At RH, 97% of the gusts were slower than 30 mph. However, the absolute magnitude of the gusts is not important for the present purpose. Rather, the important information to extract from this figure is the relative magnitudes of the gusts at each of the three sites. In any given year, the bulk of the data will probably lie in the 30 mph and lower range, as it did in 2005. However, this data is relatively unimportant from a driving perspective. At the upper end of this range, say from 25-30 mph, drivers need to exhibit greater caution, but driver's of the Palouse regularly experience these conditions in the winter, regardless of where they drive. It is the upper-tail area of the histogram that is important for the purpose of this study. In order to focus on this more extreme data, it is reproduced in the Figure 2, with an exaggerated vertical scale, which ranges from 0 to 1.8%, and includes only the ranges of data in excess of 30 mph.

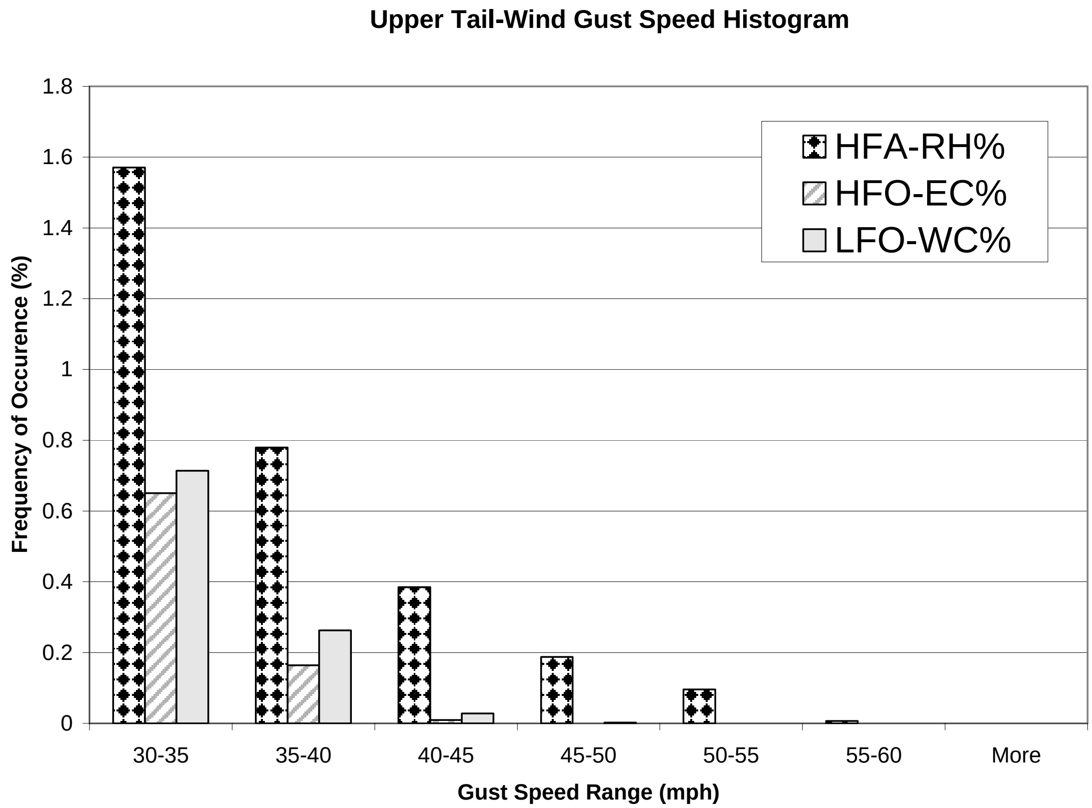

Figure 2. Histogram of the upper-tail of wind gust speeds, for gusts in excess of 30 mph.

Regardless of the actual magnitudes of the data in Figure 2, one can see that the frequency of occurrence in each bin or range is similar for the EC and WC sites, and the frequency of occurrence in each of these "high speed" bins is larger for the measurements at RH. Furthermore, gusts in excess of 50 mph were observed only at RH. The differences in gust speeds among the three measurement stations may be examined in more detail by means of scatter plots of gust speeds. Figures 3 and 4 below show scatter plots of the gusts at RH versus WC and RH versus EC, and the Figure 5 shows EC versus WC.

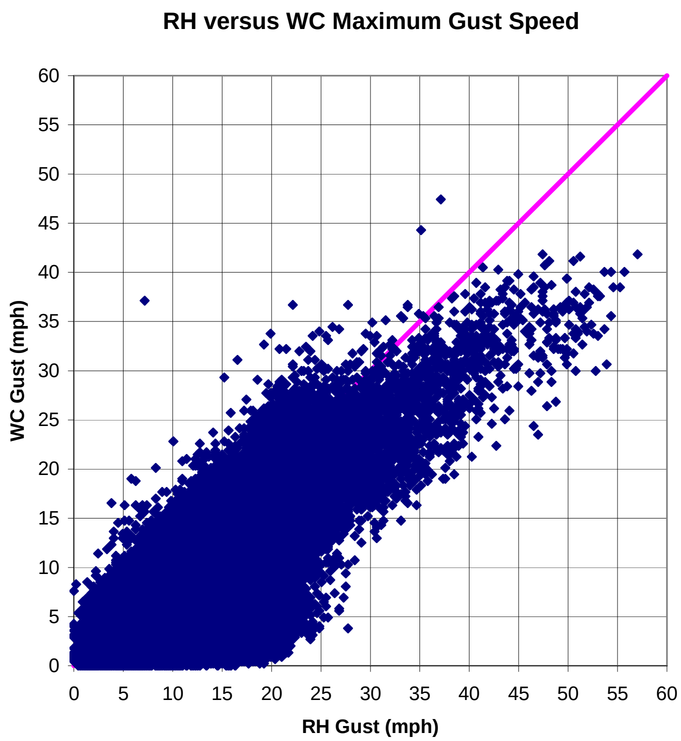

Figure 3. Scatter plot of gust speeds at RH versus WC.

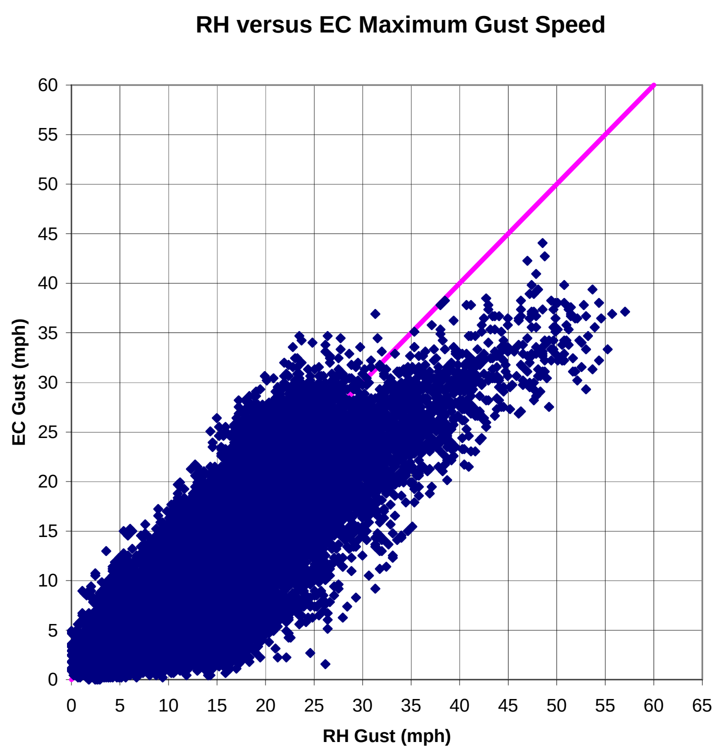

Figure 4. Scatter plot of gust speeds at RH versus EC.

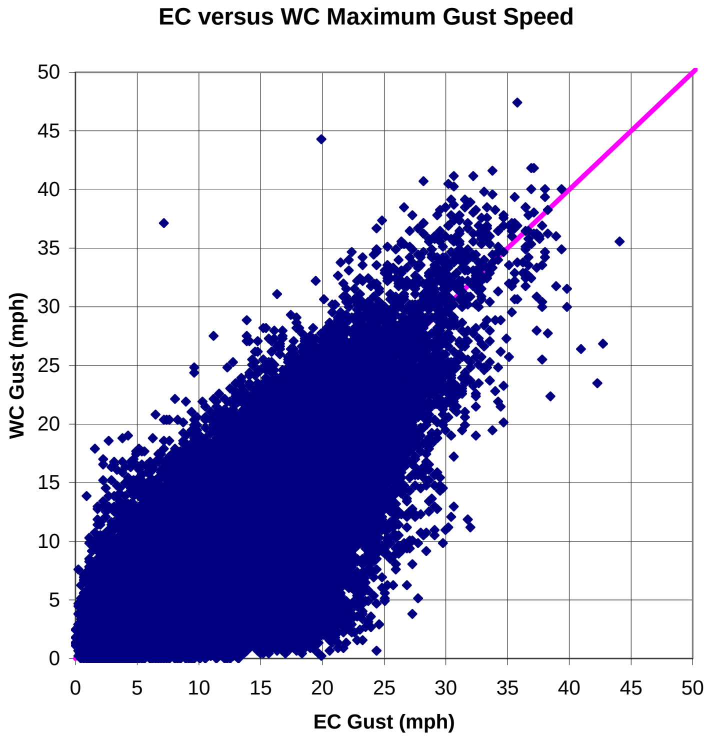

Figure 5. Scatter plot of gust speeds at WC versus EC.

Each data point on Figures 3 through 5 is an ordered pair consisting of the peak gusts measured at the two sites indicated on the axes of each graph during the same 5-minute interval. Each of these figures includes a diagonal line with 1:1 slope through the origin. Data points that lie above this line correspond to times when the gust speed at the site indicated on the vertical axis exceeded the gust speed of the site indicated on the horizontal axis. Conversely, data points that lie below the 1:1 line correspond to faster gusts measured at the site indicated on the horizontal axis compared to the site indicated on the vertical axis. I will focus my comments on gusts in excess of 30 mph. In Figure 3 (RH versus WC), the overwhelming majority of the points for which the gusts exceeded 30 mph at one or both of the two sites, lie below the 1:1 line, indicating that whenever gusts exceed 30 mph, they are almost always faster at RH than WC. Figure 4 shows a similar result in the comparison between RH and EC. Namely, when gusts exceed 30 mph, they are almost always faster at RH than at EC. In both cases, RH gusts exceed the gusts at the other two sites, sometimes by as much as 20 mph, but never by much more than that. Figure 5 compares the gust speeds at EC and WC. At these two sites, when wind speeds exceed 30 mph, there is a slightly higher proportion of occurrences where the gusts at the WC site exceed those at the EC site, but generally not by more than about 10 mph.

The general characteristics of the three sites are as follows: RH is a highland site whose predominant weather patterns move around the southern end of Paradise Ridge; EC is a highland plateau which lies adjacent to the abrupt ascent up western side of Paradise Ridge; WC is a lowland site which sits in a relatively flat drainage valley, with small knolls partially blocking the wind from the Southwest clockwise through the Northwest, from the North clockwise through Northeast, and from the Southeast clockwise almost to the Southwest. Flat valleys run to the Northwest, to the East and to the Southwest from WC. Both WC and EC have predominant weather patterns which flow up over Paradise Ridge to the East.

Given the apparent similarity in the exposure of EC and RH, one would anticipate that they would experience similar wind conditions, but the data showed EC and WC to be more similar to each other, and RH to experience faster wind speeds than either of the other two. Since RH represents the southern portion of the study area, through which the existing U.S. Highway 95 and any possible proposed alternatives must run, it appears that vehicles are already exposed to the most severe wind conditions of the study area, and all of the proposed alternatives will continue to be exposed to these same severe conditions in the southern portion of the study area. Consequently, the effect of wind on vehicles in general, and large trucks in particular, should be no worse than what is currently experienced. The effects of the depth of fill sections on travel lane wind speeds are addressed in a separate report of a wind modeling study conducted for ITD. The conclusions of that study were that depth of fill should not pose a significant problem with regard to wind.

Secondly, despite their apparent difference in exposure, the similarity in wind speeds measured at the two stations EC and WC indicates that the entire middle third of the study area, whose predominant weather pattern flows over Paradise Ridge, experiences similar wind speeds. There may be specific features in this area which locally reduce the wind such as trees along the roadway, or deep road cuts, although these can cause their own problems in terms of road ice and snow accumulation. However, the measurements at the WC site indicate that even portions of the road in low lying areas or valleys can experience winds as severe as the exposed plateau of the EC site. Thus, the data do not support the conclusion that traffic on eastern corridor alternative alignments will have greater problems with wind than other proposed alignments in the central or western corridors.

Temperature Lapse Rate

There were a number of comments about the decrease of temperature with elevation, or temperature lapse rate, which is familiar to most people. The temperature lapse rate with elevation is a reasonably well-understood thermodynamic phenomenon. Under well-mixed conditions, for example during windy weather or when there is strong heating of the surface by the sun to produce significant convection, the lapse rate is *generally positive, where a positive lapse rate means the temperature decreases, or "lapses", with increasing elevation. The thermodynamics are developed by combining the equation of state of an ideal gas, the second law of thermodynamics, and the hydrostatic approximation which governs the rate of change of pressure with elevation (Iribarne and Godson, 1981). The full development of these goes beyond the scope of this discussion, but suffice it to say that if a parcel of air were to ascend up through the atmosphere, the atmospheric pressure which surrounds that parcel would decrease with elevation because there is less weight of air piled above the parcel the higher it goes. From the ideal gas law, as pressure decreases, so does temperature. As a result, a parcel of air which is raised without exchanging heat with its surroundings, has its temperature decreased with height. This process is known as adiabatic expansion for an ascending parcel of air, and adiabatic compression for a descending parcel.*

The actual rate at which this lapse occurs depends on whether the parcel of air is dry (i.e., unsaturated) or saturated. In the dry case, the lapse rate is about 0.00548 °F/ft, and in the moist case, the lapse rate is about 0.003018 °F/ft (Dutton, 1986). The dry adiabatic lapse rate represents the upper limit to the absolute rate of temperature decrease of the atmospheric column with height, due to hydrostatic stability of the atmosphere (Barry, 1992). Actual environmental lapse rates may exceed this such as results from strong surface heating, but this produces unstable conditions which result in mixing and drives the lapse rate back toward the dry lapse rate (or the saturated lapse rate for a saturated atmosphere).

For the 400 foot elevation difference between the Eastern Corridor station, EC, and the Western Corridor station, WC, these lapse rates translate into differences between WC and EC of 2.2 °F for dry air, and 1.2 °F in the saturated air case, with WC warmer than EC. The dry case represents the largest temperature difference that can be sustained; If the temperature difference gets larger than these numbers, e.g., if the temperature at the lower station, WC is more than 2.2 °F warmer than the air at the EC station, the air parcel at WC would become less dense and therefore lighter than the air at EC. When lighter air resides below more dense air, buoyancy drives the lighter air upward, in the same way that buoyancy causes a ball which has been forced to the bottom of a swimming pool to float upward. This buoyancy causing mixing, and restores the proper temperature lapse rate in the atmospheric column. The time scale for this to occur is generally about 15 minutes.

In our measurements, there were limited cases amounting to only a few percent of the time, when WC was warmer than EC by more than the 2.2 °F prescribed by the dry air lapse rate. This can occur, for example, when the sun shines at WC, and EC is shaded by clouds, causing the surface and air to be warmed more at WC than EC. The maximum difference that was observed with WC warmer than EC was 6.5 °F, which occurred one time over a five minute period throughout the entire five months reported in the climate study. The average difference when WC was warmer than EC was 1.78 °F which is very near the midpoint between the dry and moist air lapse rate *temperature differences. The fact that the average temperature difference between the two stations lies very close to the midpoint between a very narrow range of expected temperatures provides significant confidence in the accuracy and precision of the measurements.*

Figure 6 plots the temperatures at EC against the corresponding temperatures measured at WC.

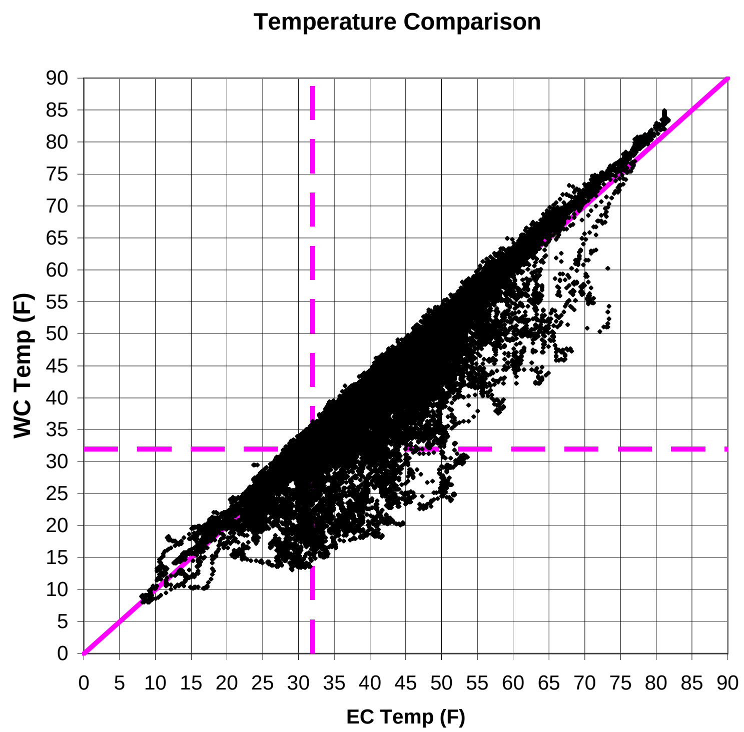

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Figure 6. Scatterplot of air temperature at_EC_versus WC.

In Figure 6, the solid line represents the one-to-one slope along which temperatures at the two sites were equal. Points above this line have EC colder than WC. Points below the line have WC colder than EC. The vertical and horizontal dashed lines represent the freezing temperature at EC and WC, respectively.

As is apparent from Figure 6, there are many more points with WC colder than EC, more than three times as many, and the temperature differences are much larger when WC is colder than EC. The upper limit imposed by buoyancy constraints on the temperature lapse rate as to how much warmer WC can be than EC is clearly shown by how tightly and uniformly the points above the line lie in proximity to the line.

It is very important to note how small the upper limit to the sustained temperature difference between the WC and EC stations is in relation to the possibility of producing sub-freezing temperatures at EC while WC is above freezing. In "fig-T_EC_WC" this *situation corresponds to the region in the graph above and to the left of the intersection of the two dashed lines demarking freezing temperatures. Given the narrow, lapse rate imposed range of the temperature difference when WC is warmer than EC, i.e., 2.2°F, both temperatures must be very near freezing in order to produce the situation where WC is above freezing and EC is below. This significantly reduces the frequency with which this occurs, and is demonstrated by how few points occupy the upper left quadrant in Figure 6. Of course if the stations had a much larger vertical separation, such as between the city of Moscow and the top of Moscow Mountain, the temperature difference would have the potential to be much larger, 7.9 °F to 14.4 °F, for the saturated and dry adiabatic expansion cases, respectively. In this case the opportunity for Moscow Mountain to be below freezing while the city of Moscow is above freezing is greatly increased simply owing to the greater difference in their temperatures.*

There is another opposing factor to the positive lapse rate I have just discussed. In the evening, the surface and near surface air begin to cool. If this occurs non-uniformly in space, then some air ends up being cooler than other air. By the ideal gas law, the cooler air is more dense. This dense air will sink to the ground and "flow" downhill, just as water does during a heavy rainstorm. This cold air drainage, known as a "katabatic" wind, follows the topography sinking to the lowest spot accessible from its point of origin, pools there, and produces a negative lapse rate, in which the temperature is colder at lower elevations than at higher elevations. This phenomenon does not require a large scale inversion to be in place to occur and occurs over land sloping more than about 2°, and it will generally occur at night unless there is regional wind in excess of 11 mph present to prevent it (Linacre, 1992). It regularly happens at night, and occurred throughout the measurement period with great frequency, and based on spot checks I have made of the data stream this winter, it is occurring again this year. The magnitude of the temperature difference will be larger when clear skies exist owing to greater radiative cooling of the surface, but clear skies are not required for katabatic winds to occur.

This cold air drainage phenomenon is apparent from all the data that lie below the one-to-one sloped solid line. The area of Figure 6 which is of particular interest here is the lower right quadrant, which represents points where temperatures are sub-freezing at WC, and above freezing at EC. There are numerous points in this region, and the temperature differences between WC and EC are much more extreme.

Once this stratification is established, it produces very stable conditions which require an external energy input to be broken up. Thus once it is established, it often persists until morning. The breakup can occur either by the external imposition of wind such as from the passing of a front, or by heating of the ground which warms the cold air, so that it then mixes upward with the air aloft due to buoyancy, and restores the positive lapse rate discussed above.

Unlike the adiabatic expansion process, this cold air drainage is not subject to the same kind of maximum temperature difference limitation as adiabatic expansion. The lower elevation site can become much colder than the upper site.

Comparing the relative frequencies with which EC was below freezing, and WC was above and vice versa, reveals that during the study period, there were cumulative totals of 71 hours for the former case, and 226 hours of the latter; thus WC was sub-freezing while EC was above freezing more than three times as often as the converse situation. Even if the mean temperature was warmer or colder, as it might be in a different year, this would likely only shift the temperatures up or down along the one-to-one line, and would not appreciably change either the numbers of hours in each category, or the relative frequency with which they occur. The region of "space" on the graph, the upper left quadrant, is simply too restrictive for there to be a large quantity of hours subject to EC below freezing with WC above.

The lapse rate discussion can be summarized as follows. When the air is well-mixed either by wind or by convection such as results from heating of the land surface, one can usually expect a positive lapse rate, that is a decreasing temperature with increasing elevation. The greater the vertical distance, the greater the temperature difference. The 400 foot vertical separation between the EC and WC sites was enough regularly to produce an average difference of 1.78 °F (calculated including only values of the temperature difference in which EC was colder than WC), which closely matches the theoretically expected difference of between 1.2 and 2.2 °F. This small difference limits the frequency with which the situation occurs where EC is below freezing and WC is above freezing. Cold air drainage can occur year round, generally occurs at night, and produces a stable temperature profile with cold temperatures at lower elevations. The temperature differences between the upper elevation site and lower elevation site can be much larger during these cold air drainage periods than the differences corresponding to the case where the upper elevation site is cooler.

Snow Distribution in Study Area

The depth of snow in a location is determined by the balance of past deposition and melting. Deposition of snow depends on depth of precipitation at a given location, and a sufficiently cold temperature to cause the precipitation to fall as snow rather than rain. In high topographic relief areas, including the Moscow, Idaho area, the depth of precipation tends to increase with elevation, and the temperature tends to decrease, as discussed in the previous section. In fact the increase of precipitation is largely governed by the altitudinal decrease of temperature, which causes increased condensation and cloud formation in air masses, and hence more precipitation at higher elevations than at lower. Over large elevation differences, such as between the City of Moscow (2600 feet), and the top of Moscow Mountain (4983 feet), which differ by nearly 2400 feet of elevation, this difference is significant. As noted earlier, the temperature differences based on the saturated or dry adiabatic lapse rates between *the City of Moscow and Moscow Mountain are 7.9 °F to 14.4 °F, respectively. Based on snow measurements at the Moscow Mountain SNOTEL site, this is sufficient so that at the time of this writing (March 29, 2006), there is 56.4 inches of snow on the ground or 21.6 inches of snow water equivalent near the top of Moscow Mountain, and a temperature difference between Moscow Mountain and the UI Plant Sciences Farm of 9.1 °F.*

Although the Climate study reported a precipitation difference between the Eastern Corridor and the Western Corridor, presumably due to the elevation difference, and the close proximity of the plateau of the EC site to Paradise Ridge, the temperature differences are not sufficiently large to sustain long-lasting differences in accumulated snow between the EC and WC sites. Certainly there are times when it snows on the EC plateau, but does not snow in the City of Moscow, or at the WC site, and sometimes the snow persists on the EC Plateau when it does not at lower elevations. As noted earlier, the small difference between the temperatures at EC and WC and the infrequency with which WC and EC reside on opposite sides of the required temperature to allow snow at the upper site and rain at the lower reduces the frequency at which this might be expected to occur. In order to get a good idea of the frequency of persistent snow at EC when there is none at WC, one must consider the causes of snowmelt.

Melting, or snow ablation, is primarily caused by a flux of energy into the snow pack. There are three primary sources of energy for snow melt: solar irradiance from sunshine, heat released by the condensation of water vapor onto the snow surface, and heat absorbed from warm winds blowing over the snow also known as convection (Linacre, 1992). Convective melting can be calculated as,

$$M_c = 0.19u\left(T_a - T_s\right)$$

where M_c is the melting rate in mm/day liquid water equivalent, u is the wind speed at two meters height above ground in m/s, T_a is the daily average air temperature and T_s is the temperature of the snow surface both in °C. T_s may be taken as 0°C, especially during melting conditions, and dropped from the equation. If the air temperature is colder than the temperature of the snow, no melt occurs. If we want to consider the difference in melting rates between the WC site and the EC site, we can use the difference in the air temperature of the two sites, which has a mean daytime value of about 1.78 °F, or 0.99 °C, and the mean site wind speed, adjusted to 2 meters height, which is 6 m/s. This produces a difference of 1.1 mm/day, or roughly about 0.04 inches greater melt per day at WC due to convection than at EC. Note that frequently the temperature difference does not persist through the night, and often changes sign, so that EC is warmer than WC, 3.6 mm/day difference is probably an overestimate.

Similarly, condensation melting can be calculated as,

$$M_d = 0.6u\frac{\Delta}{\gamma}(T_d - T_s)$$

where M_d is the condensation melting in mm/day liquid water equivalent, Δ is the slope of the saturation vapor pressure curve at the surface of the snow which has a value of about 0.5 hPa/°C, γ is called the psychrometric constant and has a value of about 0.6 hPa/°C, T_d is the daily average dewpoint temperature in °C, and all the other input variables are the same as for convection melting. The coefficients in the equations for convective and condensation melt account for unit conversions, the effects of the latent heats of fusion and of sublimation, and effects of turbulent energy exchange between the air and the surface. Different values of the coefficients appear in the literature, however, whatever values are used in a particular equation should be similar when compared between the different sites As with convection melting, we can determine the difference of melt which would be expected between EC and WC. The differences in dewpoint temperature between WC and EC are close to the difference between the air temperatures, namely, 1 °C. This again produces a difference in melt rate of 3.6 mm/day or one-eighth of an inch per day. Generally the temperatures are colder at the RH site in the southern climate regime of the study area. Consequently, convective and condensation melting there would be less than occurs at the EC site.

The final important source of energy is net radiation, or the balance of the incoming and outgoing components of solar and terrestrial radiation, given by,

$$Q_n = (1-\alpha)R_s - R_{nl}$$

where Q_n is the net radiation in W/m², R_s is the incoming solar radiation, in W/m², α is the albedo or fraction of incoming solar radiation that is reflected by the surface and which ranges from about 0.9 for fresh new snow, to about 0.4 for old dirty snow, and R_{nl} is the net outgoing longwave radiation, in W/m². If Q_n, R_s, and R_{nl} are taken as 24-hour averages, or are integrated over 24 hours, the net radiation input to the snowpack in W m^{-2} can be converted to snowmelt in mm/day by multiplying Q_n by 0.254.

Net longwave outgoing radiation consists of the longwave radiation emitted by the surface minus the incoming longwave sky radiation, plus the reflected fraction of the incoming longwave sky radiation.

$$R_{nl} = \varepsilon_s \sigma T_s^4 - \varepsilon_s \varepsilon_{sky} \sigma T_a^4$$

where ε_s is the surface emissivity taken as 0.97, σ is the Stefan-Boltzmann constant (=5.6697 x 10^{-8} W m^{-2}K^{-4}), ε_{sky} is the sky emissivity taken as 0.97 for heavily overcast conditions and as 0.76 for clear sky conditions, T_s is the snow surface temperature, taken as 0°C during melting, and T_a is the air temperature at 6 feet above the ground. As a result, since all three sites, EC, WC and RH are exposed to the same sky conditions, their incoming longwave radiation components would be very close to one another in magnitude. Similarly, when snow is present at all three sites, the surface temperature would be close to 0 °C at all three sites so their values of emitted radiation would also be close to one another. In general, net longwave radiation results in a loss of energy from the surface when the sky is clear, and may result in a net gain of energy by the surface when the sky is cloudy if the air temperature is above about 1 or 2°C.

Solar radiation was measured at each of the climate stations in the study area. Comparison between the measurements at the three sites showed that their five-month averages only differed by about 3 W m^{-2}, which is smaller than the stated accuracy of the instruments. Daily peak values in the 350 W m^{-2} range in early January, in the 600 W m^{-2} range by March, and above 900 W m^{-2} in late May were observed. These corresponded to daily 24-hour mean values of around 75 W m^{-2} in early January, 175 W m^{-2} in early March, and nearly 350 W m^{-2} by the end of May. In comparison to these numbers, the 3 W m^{-2} difference between the radiation measured at the stations is negligible.

One can model snowmelt caused by the three dominant melting factors, convection, condensation, and radiation using the equations given above. Given a starting point snow depth, one can model the snowmelt, or ablation, subtract the ablation from the starting depth to estimate the current depth of snow on the ground. This modeled depth can be compared with measured snow depth to determine how accurately the model represents the melting events at a given site, and can be used as a useful tool to compare rates of melting and or persistence of snow at different points in the study area.

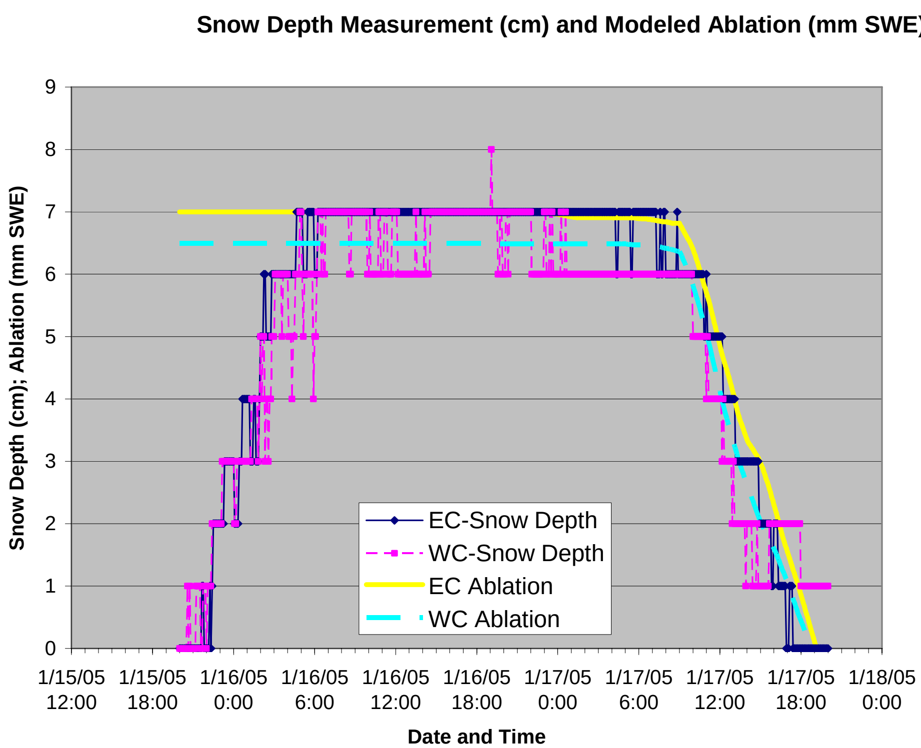

Figure 7. Comparison of snow depth measurements with modeled ablation.

Figure 7 illustrates the use of this snowmelt model at the EC and WC climate sites, compared to snow depth measured with a sonic snow depth sensor, for a snowfall and *ablation event which occurred on January 15, 16, and 17, 2005. The snow depths are reported in units of centimeters, which can be divided by 2.54 to get inches. The sonic snow depth measurement at the WC and EC sites reported 6.5 cm (2.56 in) and 7 cm (2.76 in) of snow accumulation, respectively, reported as actual depth of snow on the white snow collection board. Independent precipitation depth measurements as snow water equivalent, SWE, (i.e., the liquid depth of water the snow would contain if it were melted) at the two sites indicate that during this snowfall event 6.51 mm and 6.66 mm of SWE fell at WC and EC, respectively. Comparisons of precipitation depth measurements in SWE units of mm with snow depth in cm during this same snow event, indicate that the density of the snow was approximately 10% (100 kg m^{-3}) at WC and 9.5% (95 kg m^{-3}) at EC, compared to the density of liquid water, both of which fall in the middle of the normal range for new snow densities (Pomeroy and Gray, 1995). As a result, centimeters of snow depth and millimeters of liquid water ablation are just about directly comparable, that is, a reduction of 1 cm solid snow depth is approximately equal to ablation of 1 mm liquid water. However, as snow melts, the meltwater drains into the snowpack, and may cause subsidence of the snowpack at a slightly faster rate than the actual rate at which melting occurs (Kattelmann and Elder, 1993). Hence, the measured depth of snow from the sonic depth sensor might decrease slightly faster than the snow actually melts.*

There are several features which can be observed from Figure 7. One is that the accumulated depths are similar at the two sites, and are fairly well synchronized. The snow depth sensor only changes in 1 cm steps. Some of the oscillation associated with the measurements may be associated with blowing snow during the accumulation period; as the snow piled up, wind redistribution may have caused the depth to oscillate between two adjacent measurement values. This is particularly evident at the WC site during the accumulation stage, and before the beginning of ablation. There was much less oscillation once melt began, perhaps since once the snow begins to melt, it cannot be blown around by the wind.

Secondly, the ablation calculated based on data measured independently at EC and WC also track each other fairly well. The difference between the two is primarily an artifact of the starting point of each curve corresponding to the mean depth of snow at the end of the snow event. At least for this particular snow accumulation and melt event, the variables the variables used as input from the two sites were close enough that the simulated melt rates were very close, and the field observations of the decline in snow depth corresponded closely with the simulated values.

The fractions of total melt corresponding to convection, condensation, and net radiation were 0.25, 0.34, 0.41, respectively at WC, and 0.28, 0.28 and 0.43, respectively at EC. Prior to January 17th, no significant melting occurred since temperatures were well below freezing, and , and radiation was limited. During the mid-day period on January 17th, net radiation dominated the other two terms by about a factor of three, whereas in the late afternoon and early evening, condensation melt exceeded convection and *radiation melting by factors of about two and five, respectively. The relative fractions of melt for each of the components were of similar values between EC and WC. That is, radiation caused about the same amount of melting at EC as at WC, and the same may be said of convection and condensation melting when comparing the two sites. Also note that the combined fractions of melt caused by condensation and convection, the two components most dependent on air temperature, humidity, and wind speed were similar between EC (0.59) and WC (0.56).*

This leads to the point of the foregoing analysis. Observations from Moscow sometimes indicate that there is occurrence and/or persistence of snow on the highland plateau of the Eastern Corridor and an absence of such in the Western Corridor. How can these observations be reconciled with a) the fact that predominant mechanisms of snowmelt that indicate that snowmelt should occur at relatively similar rates at both EC and WC, and b) that measurements at both sites indicate that snowfall at EC is regularly accompanied by snow at WC? This may be explained in light of the one factor that varies significantly around the study area: radiation loading as a function of slope and aspect of the land surface. The snowmelt information shown above corresponds to measurement sites which were approximately level, and all the radiation calculations assumed a level land surface. However, the interaction of the position of the sun at a given moment, and the slope and aspect of the land surface has a tremendous impact on the amount of solar radiation absorbed by the surface. Slopes with a south-facing aspect point more directly toward the sun and receive more radiation per unit area tangent to the surface; slopes with a northern aspect tilt away from the sun and receive much less radiation. The following table presents multiplication factors for the amount of radiation received on a sloped surface relative to a horizontal surface for two different combinations of slope and aspect and a few different dates during the winter. The multiplication factors have been adjusted to allow for diffuse radiation, and have been integrated throughout the day. The combinations of slopes and aspects presented are abundantly present in the study area.

Table 1. Radiation Loading Factors relative to a horizontal surface, for 16° slopes and aspect oriented either directly north or south.

Aspect	*Date*	*Factor*
South	*January 1*	*1.79*
North	*January 1*	*0.14*
South	*February 1*	*1.56*
North	*February 1*	*0.37*
South	*March 1*	*1.35*
North	*March 1*	*0.58*
South	*April 1*	*1.21*
North	*April 1*	*0.72*

The factors in the table above may be used to adjust the solar radiation flux density to the amount received by the surface with the specified slope and aspect given the *radiation flux density received by a horizontal surface at the same location. For example, on January 1, the 24-hour average clear sky solar radiation on a horizontal surface is approximately 74 W m^{-2} in the study area. The 24-hour average solar radiation on a south-facing, 16° slope is 1.79 times the horizontal surface amount, or 132.5 W m^{-2}, and has 179% of the melting capability of the horizontal surface; on a north-facing, 16° slope the factor is only 0.14, so the 24-hour average solar radiation on that slope is only 10.4 W m^{-2}, or 14% of the horizontal slope radiation. If one considers the radiation loading ratio of south-facing to north-facing slopes, the differences become even more pronounced. For example, on January 1, the ratio of radiation loading on a south-facing, 16° slope to a north-facing slope is 12.8 (=1.79/0.14). That means there is 12.8 times more radiation received on a south-facing slope than on a north facing slope. This radiation difference translates proportionally into melting differences between south- and north-facing slopes. In the example given above, for an old snow with an albedo of 0.4, this radiation load would result in the snow water equivalent melting of 20 mm (0.79 inches) on a south-facing slope, 11.2 mm (0.44 inches) on a horizontal surface, and 1.6 mm (0.06 inches) on a north-facing slope. Of course, convection, conduction and longwave radiation are other melt terms, but when temperatures are below freezing these factors contribute little or no melting, and when temperatures are above freezing, as shown in Figure 7 above, elevation does not make a significant difference. If anything, the north-facing slopes would tend to be colder because there is less radiation heating of the surface to heat the air directly above it, which would exacerbate the already existent difference between melting rates on north and south-facing slopes. As a result spatial variability in melt rates are much more strongly tied to slope and aspect within the study area than they are to elevation.*

The following photographs illustrate this north-south radiation snowmelt phenomenon within the study area. The photographs were taken following a relatively light snowfall, which fell between 1:00 and 1:30 a.m. at all three sites in the study area. During the same time, 0.5 inches of snow fell at the UI Plant Sciences Farm, which was equal to 0.06 inches of Snow Water Equivalent, or liquid water depth.

Photograph 1 View toward the northern side of the plateau of the eastern corridor of the study area showing fresh snow on the north-facing slopes (DSC_0100).

Photograph 1 was taken from the south side of Moscow, looking south toward the plateau of the eastern corridor of the study area showing fresh snow on the north-facing slopes. Columbia Tractor sits in the right foreground, and the buildings in the center of the photograph are on Palouse River Drive, just east of U.S. 95. The low lying ground in the center of the photograph has an elevation around 2550 feet above mean sea level, and the high area on the left side of the photograph, just at the edge of the treeline is approximately 3100 feet amsl.

Photograph 2 was taken near the cell tower at Reisenauer Hill looking northward, toward the south-facing side of the eastern corridor plateau. This is the backside of the slope shown in photograph 1. No snow is visible anywhere in this photograph, because everything within view of the camera, which was pointing north, had a southern exposure. Hidden Village lies in the foreground at the bottom of the hill at an elevation of about 2750 feet amsl; the right side of the photograph goes up to an elevation of about 3100-3200 feet amsl.

Photograph 2. View toward the southern side of the plateau of the eastern corridor of the study area showing south-facing slopes devoid of snow (DSC_0132)._

The next two photographs are from the western corridor of the study area, along Snow Road. Photograph 3 points south, looking at north-facing slopes, and some flat ground. The snow-covered ridge running East-West across the foreground of the photograph has an elevation of about 2560 feet amsl on the right side of the photograph; the north-facing slopes in the background are also snow-covered.

Photograph 3. Southward looking view from Snow Road toward north facing slopes in the western corridor, and in the southern portion of the study area (DSC_0106).

Photograph 4. Northward looking view from Snow Road toward south-facing slopes in the western corridor (DSC_0105).

In contrast to photograph 3 is photograph 4, which was taken from the same point as 3, but shooting toward the north with south-facing slopes in view. The photographs were taken within the same one minute interval.

Photograph 5 shows an eastward looking view of the eastern corridor from Zeitler Road. Here the contrast between either flat or south-facing slopes, and slopes with a north-facing aspect is evident. The snow covered slopes face northwest. Since the photographs were taken before 10 a.m., the sun was still to the east, so that northwestern slopes had not yet been exposed to direct solar radiation. Note that flat and south-facing slopes both in the low-lying foreground, and at higher elevations in the background are free of snow.

Photograph 5. Eastward looking view from the beginning of Zeitler Road, right after the turn off from U.S. Highway 95 (DSC_0111).

The only view of the study area from the City of Moscow is of the slope leading up to the highland plateau of the eastern corridor. The western corridor is hidden behind Clyde Hill, and the Highland Flow Around area occupying the southern one-third of the study area is hidden either by Clyde Hill or by the highland plateau of the eastern corridor, depending on the viewing location. As a result of the affect of slopes and aspects on radiation loading, what one sees from Moscow is predominantly a north-facing slope. This remains snow covered for a larger percentage of time than the low *lying valley along Palouse River Drive because of the levelness of the bottom of the valley, which increases its radiation exposure, more so than because of its elevation. The south slope of the eastern corridor plateau, which faces south, is often free of snow because of its radiation exposure, even though it is at higher elevation. The ramification of this is that the appearance that there is frequently snow on the eastern corridor highland plateau when there is none at the lower elevations is misleading; the anecdotal evidence indicates a higher frequency of snow at higher elevations compared to the lowlands than actually occurs.*

Coming back to the initial concern regarding the observation of snow on Paradise Ridge and the plateau of the eastern corridor, the evidence may be summarized as follows: Sometimes the snow level will occur between the high point of the eastern corridor and the low point of the western corridor, when the freezing point happens to be located between those two elevations and precipitation is occurring. However, given the thermodynamics governing the stability of the atmosphere, the temperature difference between the EC and WC sites cannot be sustained at much more than 2-3°F with WC warmer than EC for extended periods of time. This small temperature difference limits the window of opportunity for snow to occur on the eastern corridor highland when it rains in the lower western corridor. There is much greater opportunity for it to snow across the entire study area, or to rain across the entire study area. The snowmelt model and measurements within the study area, show that the convection, conduction and radiation melting mechanisms do not exhibit significant variation with elevation, but that radiation loading contributes significantly to spatial variation as a result of slope and aspect. Photographs taken within the study area support this conclusion.

Finally, this analysis indicates that snow is likely to pose the most significant driving risk for roadways on north facing slopes. Since every possible roadway alternative within the study area must achieve an elevation above 2900 feet in the southern portion of the study area but end up at approximately 2600 feet as it enters Moscow, every possible alternative must descend a north facing slope. In the case of the proposed eastern alignments, this will occur on the slope visible from Moscow. In the case of the central and western alignments this will occur further south in the study area, but in every case it must occur.

Historical Representativeness of 2005 Measurement Period

There were a number of concerns expressed about how representative the January through May, 2005, measurement period was with respect to the local climatology. In order to evaluate this issue, one can look at the long-term historical records from the Moscow University of Idaho Cooperative Observer Station located at the University of Idaho Plant Sciences Farm. This is the same data used for the historical precipitation

analysis presented in the Climate Report for this study, and was referred to as PSF data in that report.
The records from PSF contain daily data back to 1893, however, for the climate report, and for the information presented below, I have used the more recent 30 year climatological normal period, 1971-2000, according to standard climatological practice, and have included the 2001-2005 data. The daily data set includes precipitation depth, snowfall depth, snow depth on ground at time of observation, maximum air temperature, minimum air temperature, and air temperature at the 5 p.m. time of observation. The analyses of these data, and several other variables which may be inferred from them, such as the number of days in a month with no snowfall, or no snow on the ground, are presented below.

In the analysis, I compare the 2005 winter season PSF data to the 35 year PSF historical record to determine how the 2005 PSF data ranks with respect to the historical record from the same location. I define rank as how a particular month places with respect to the corresponding month of the previous 34 years. For example, was February 2005 the warmest, 3rd warmest, 5th warmest, or 20th warmest month of the 35-year period? Since winter weather systems in the Idaho Panhandle generally have a spatial scale on the order of 100 miles, as opposed to summertime convective thurnderstorms such as occur east of the Rocky Mountains which have a spatial scale on the order of 5 miles, the ranking of the 2005 season for various variables ought to closely correspond to the ranking at the three weather stations in the U.S. 95 Realignment Project study area.

Snow
Snow data were recorded daily. These included depth of snow which fell on the current day measured to the nearest tenth of an inch, and snow depth on the ground at the 5 p.m. time of observation recorded in whole inches. The cumulative monthly snowfall depth for the months of November through March for the 35 years, 1971-2005, are shown in Figures 8 - 12 (one figure for each month). Cumulative monthly snowfall is calculated by adding up the values of daily snowfall depth. I have omitted the months of April and May from the snow analysis because historically they have little or no snow.

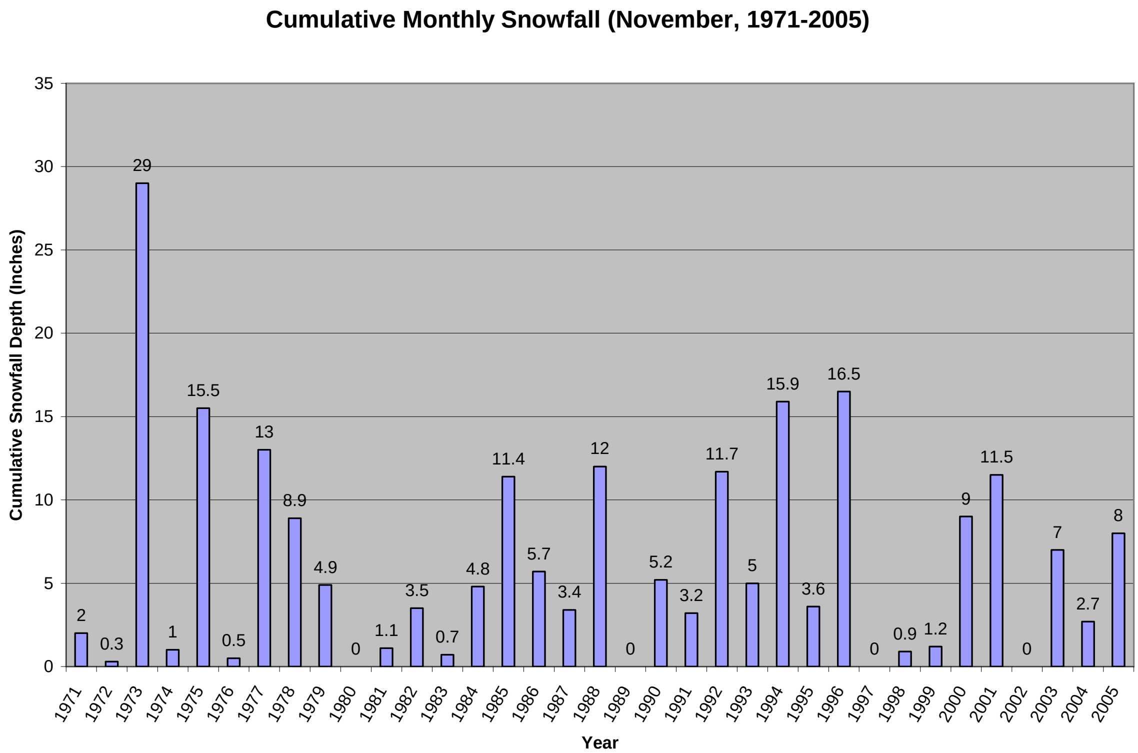

Figure 8. November Cumulative Monthly Snowfall, PSF. 1971-2005.

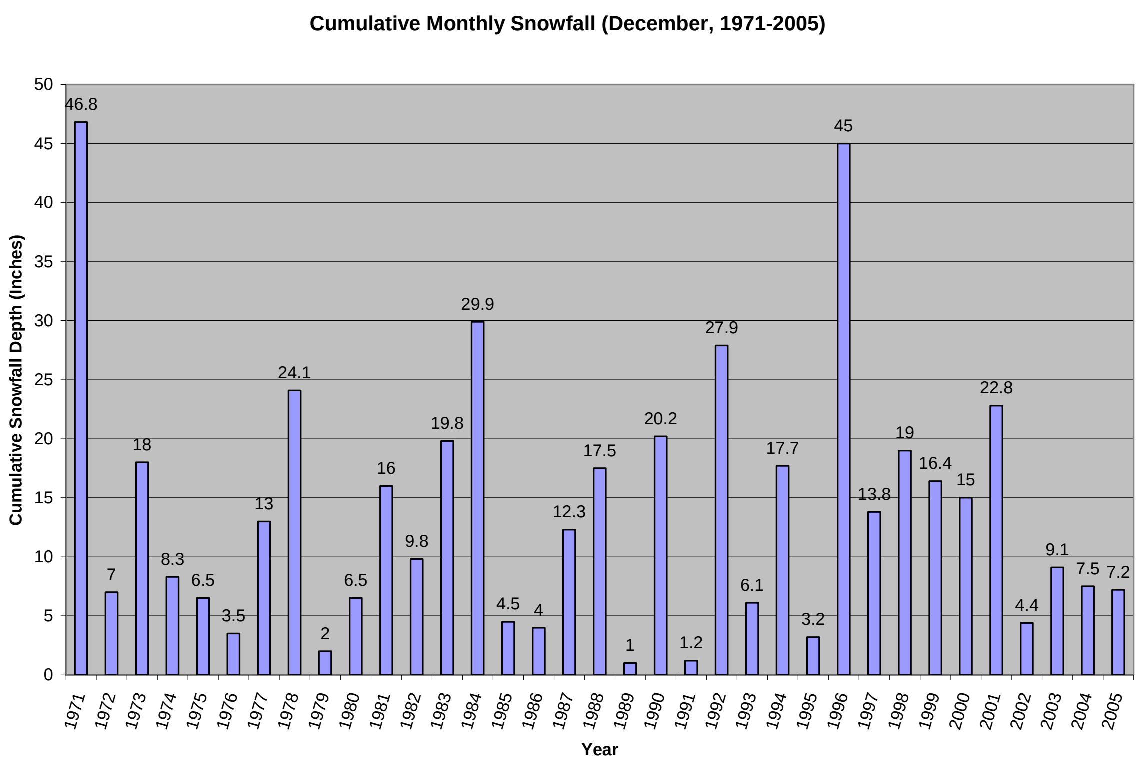

Figure 9. December Cumulative Monthly Snowfall, PSF. 1971-2005.

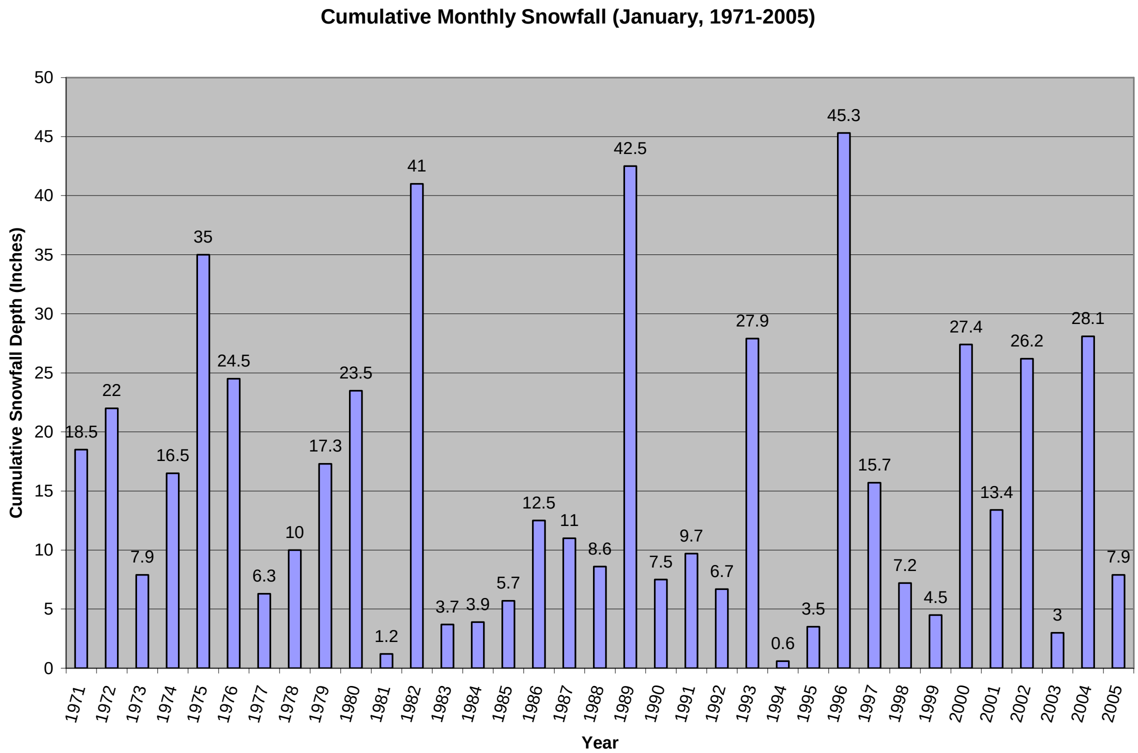

Figure 10. January Cumulative Monthly Snowfall, PSF. 1971-2005.

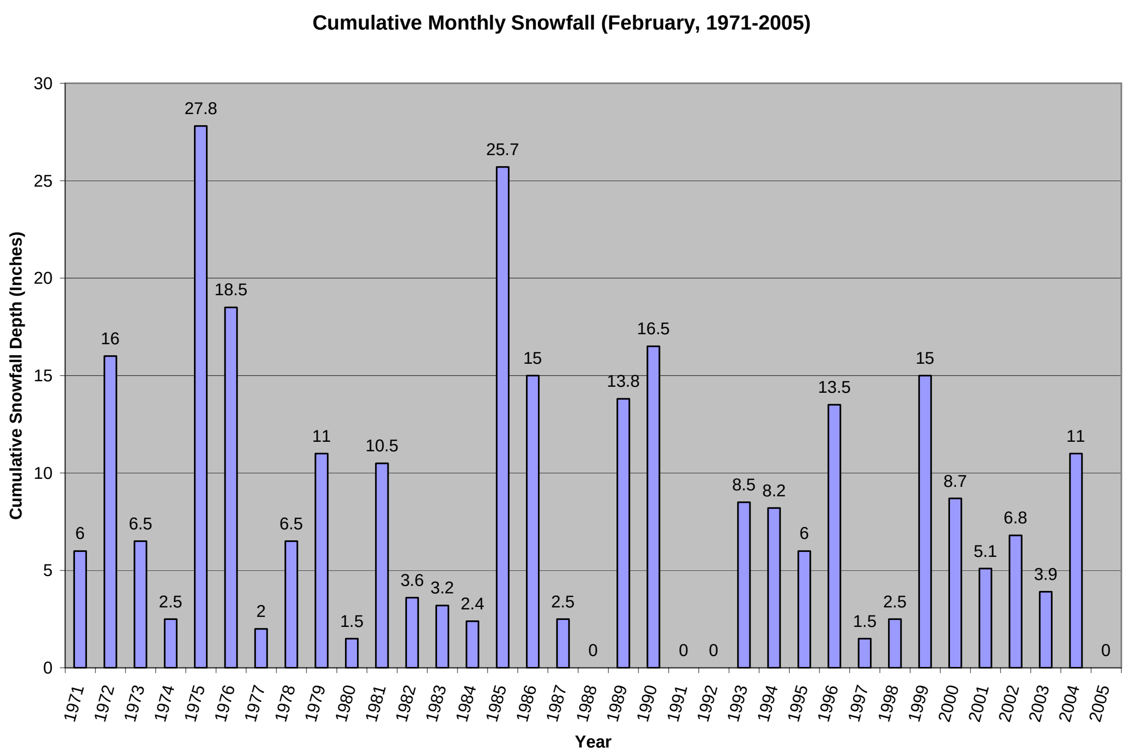

Figure 11. February Cumulative Monthly Snowfall, PSF. 1971-2005.

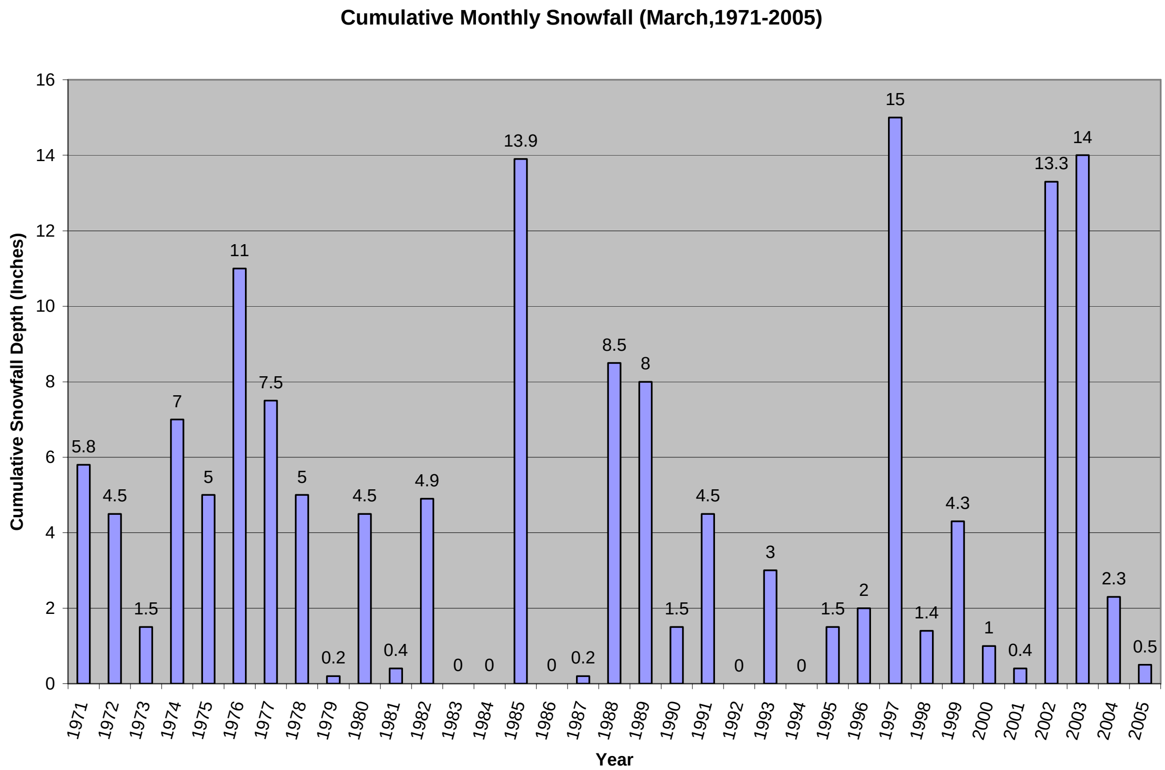

Figure 12. March Cumulative Monthly Snowfall, PSF. 1971-2005.

The November 2004 through March 2005 cumulative snowfall data can be compared to the historical data by counting the number of years from 1971 through 2005 for which the cumulative monthly snowfall was the same or less than the amount that fell each month during the November 2004 through March 2005 time period. The data are presented in the following table, beginning with the cumulative snowfall by month from the 2004-2005 winter season.

Table S1. Monthly cumulative snowfall depth at PSF during the 2004-2005 winter season, and number of other years with the same or less monthly cumulative snowfall.

Month	Cumulative Snowfall (Inches)	No. of Years with same or lesser Cum. Snowfall	Non-Exceed. Probability (%)	Return Period (Years)	Median Snowfall 1971-2005 (inches)
Nov 2004	2.7	13	37	2.7	4.8
Dec 2004	7.5	14	40	2.5	12.3
Jan 2005	7.9	14	40	2.5	11.0
Feb 2005	0	4	11	9	6.5
Mar 2005	0.5	10	29	3.4	3.0

The non-exceedance probability column represents the probability in the corresponding month in any year of receiving no more snowfall than actually occurred during the same *month of the 2004-2005 winter season. There is a 40% chance every January that 7.9 inches or less of snowfall will occur. Another way to express this is that about four years out of every ten, one can expect to receive 7.9 inches or less of cumulative snowfall in the month of January. The values in this column are calculated as the number of years with the same or lesser cumulative snowfall as the corresponding month during the 2004-2005 winter season, divided by 35 years. The return period, as I am using it here, represents the average number of years between years with cumulative snowfall depth less than or equal to that observed during the corresponding month of the 2004-2005 winter season. It is calculated as the inverse of the non-exceedance probability converted to a decimal. A non-integer return period implies that the return period brackets the number shown. For example, the return period for January snowfall less than or equal to the January 2005 value of 7.9 inches is 2.5 years, which means that the average is between 2 and 3 years. That is, based on the historical record, one would expect the average interval between years in which cumulative January snowfall was less than or equal to 7.9 inches to be 2 to 3 years. For comparison with the study period snowfall, the median snowfall over the 35 years record is provided in the final column.*

In addition to cumulative monthly snowfall, the number of days per month with no snowfall provides a useful comparison of the 2004-2005 winter season to the 1971-2005 historical period, as shown below.

Table S2. Number of days at PSF with no snowfall during the 2004-2005 winter season, and number of other years with the same or greater number of days with no snowfall.

Month	*Days with no snowfall*	*No. of other years*	*Probability (%)*
Nov 2004	*28*	*17*	*49*
Dec 2004	*26*	*14*	*40*
Jan 2005	*25*	*17*	*49*
Feb 2005	*28*	*5**	*14*
Mar 2005	*30*	*12*	*34*

**This number differs from the number of years with zero cumulative snowfall in the previous table because one leap year (1980) had 28 days without snowfall, so it was counted in this table, but not in the previous table.*

Although this does not account for snow depth, the greater the number of days of no snowfall, the milder the winter. This is particularly relevant to winter highway maintenance; the fewer the number days of snowfall, the fewer the number of days of plowing are required. In this table I report the number of years with the same or greater number of days with no snowfall, in contrast to the previous table in which I reported the number of years with the same or lesser monthly snowfall. Both of these conditions correspond to the number of years with conditions as mild or milder than the 2004-2005 winter season. The final column is the probability in percent of a winter month having the same or greater number of days of no snowfall as the same month of *the 2004-2005 winter season. November and January were both near the median number of days with no snowfall; in both cases there were 17 years out of the previous 35 years with the same or greater number of days with no snowfall. This corresponds to a 49% probability in any given year of having the same or greater number of days with no snow. December and March also had high probabilities of having their respective numbers of days with no snow, 40% and 34%, respectively. Only February was a significant anomaly, with only 5 of the previous 35 years with the same or greater number of days with no snow, which in this case was 28 days, or the whole month without snowfall. This corresponds to a 14% probability. The return period for having no days of snowfall in February is approximately one year in seven. Conversely, on average six years out of seven will have at least one day of snowfall in February.*

Depth of snow at time of observation accounts for the persistence of snow on the ground even on days when no snow has fallen, and is a measure of the period of time during the month during which temperatures remained cold enough to sustain snow. Of particular importance in measuring how mild was the 2004-2005 winter season, is the number of days per month with snow depths of zero inches. Also of importance are the number of days with snow depths less than or equal to one, two, three and four inches. These numbers are tabulated below along with the number of years from 1971-2005 which had the same number or more days, and the corresponding exceedence probability. The exceedance probability is the likelihood in any given year that there will be as many or more days with less than or equal to the specified depth of snow on the ground. As with the metrics reported above, the greater the number of days, the milder the winter.

Table S3. Number of days in 2004-2005 winter season with no more than the specified depth of snow on the ground (A Columns), the number of years from 1971-2005 with as many or more days as the number in the 2004-2005 season (B Columns), and exceedance probability (C Columns).

	Depth (inches)														
Depth (in)→	0*			1			2			3			4		
Month	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Nov '04	29	17	49	29	20	57	29	23	66	30	23	66	30	25	71
Dec '04	9	15	43	10	16	46	10	14	40	11	13	37	11	15	43
Jan '05	14	20	57	20	16	46	26	12	34	27	13	37	31	12	34
Feb '05	28	8	23	28	11	31	28	15	43	28	20	57	28	21	60
Mar '05	30	20	57	31	21	60	31	24	69	31	25	71	31	28	80

**Note that some days have no snow on the ground at time of observation even if snow fell on that day. This resulted when the snow melted between the time it fell, and the time of observation.*

For the purpose of defining how mild was the 2004-2005 winter, consider the number of days per month with zero inches of snow, and with one or less inches of snow. In the former case, the likelihood of having as many or more days as actually observed *with no snow on the ground, was in the 40 to 60% range for all months except February, for which the probability was 23%, or nearly one-quarter. For the month of February, nearly one year out of four has no measurable snow on the ground at the daily time of observation (5 p.m.). Similarly, for one inch or less, all months except February had probabilities of 46-60%, and February had a 31% probability, or nearly one year in three with one inch or less on all 28 days.*

To summarize the snow information presented above, I have considered snow in terms of the categories of cumulative monthly snowfall, number of days with no snowfall, and number of days with no more than a specified depth of snow on the ground at time of observation. I have assigned probabilities to all the variables each of which indicates the degree of severity of the snow in the specified month compared to the same months in the 1971 to 2005 time period. The probabilities correspond to the likelihood of having had snow conditions in a particular category that were the same or milder than those observed during the particular month. For example, a 10% probability indicates there was only a 10% chance that year of observing values that mild or milder, meaning there was very little snow. Conversely, a 90% probability indicates that there was a 90% probability of observing the value that actually occurred or something milder, meaning that that the snow conditions in the 2004-2005 winter season were more severe than most of the years in the historical record. All months except February during the 2004-2005 winter season had probabilities in every category between 34% and 60% (except also March 2005 cumulative snowfall depth, which had a value of 29%). The probability ranges can be broken into thirds, where events with less than a 33% probability are considered mild, events with more than a 66% probability are considered severe, and those between 33% and 66% are considered normal. By this metric, all snow categories in all months except February (and cumulative snowfall in March) fell within the middle-third or normal range. February's conditions ranged between 11% and 23% probabilities, placing that month in the "mild" range with respect to snow conditions

Air Temperature
Both the maximum and minimum daily air temperatures need to be considered with respect to their values over the 1971-2005 historical period. Within any given month, there is a tremendous amount of variability in daily maximum or minimum temperature, so that the distribution of temperatures throughout the month tends to vary across most of the entire range of historical temperatures. To give an idea of how much these variables change from day to day, I have plotted the daily values as a connected line for each year in Figures 13 to 26. For a given month, the values for each year from 1971 to 2005 are shown. The tangle of lines illustrates how variable the temperatures are throughout a given month. The data for November and December 2004, and January through May 2005 are shown as heavier lines for emphasis.

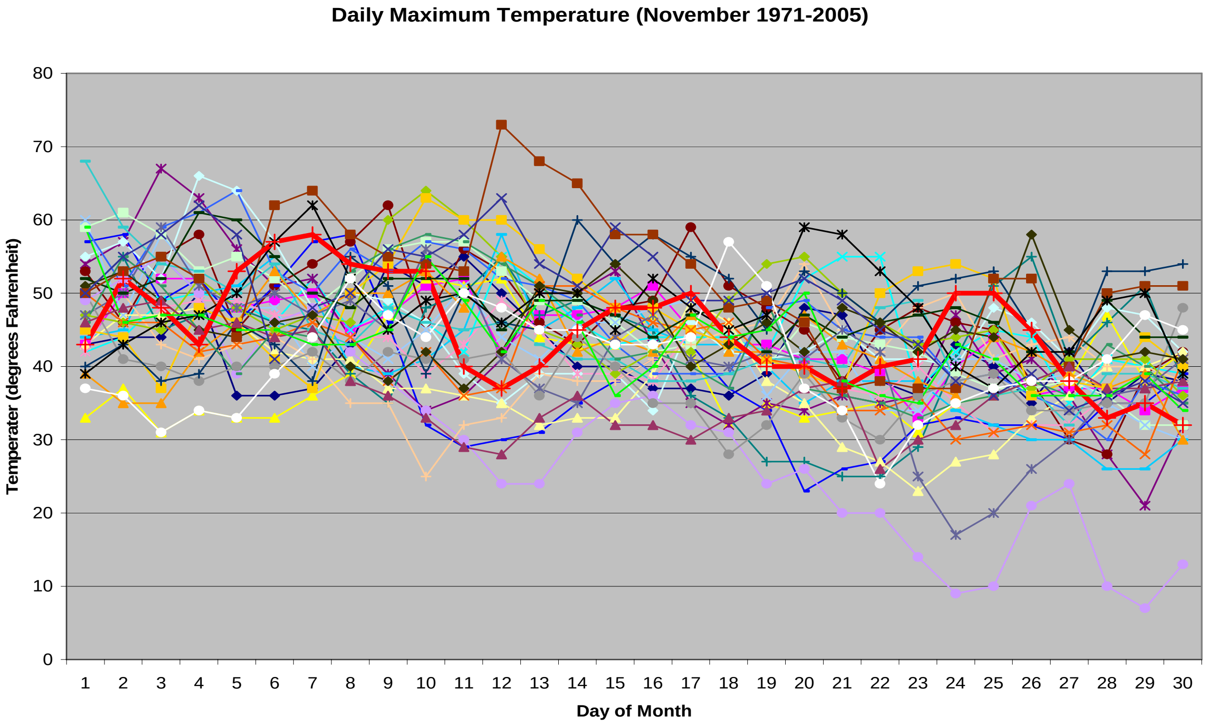

Figure 13. Daily Maximum Temperature for November from 1971-2005. Each line represents the days for a month in a single year. The highlighted red line was for the year 2004.

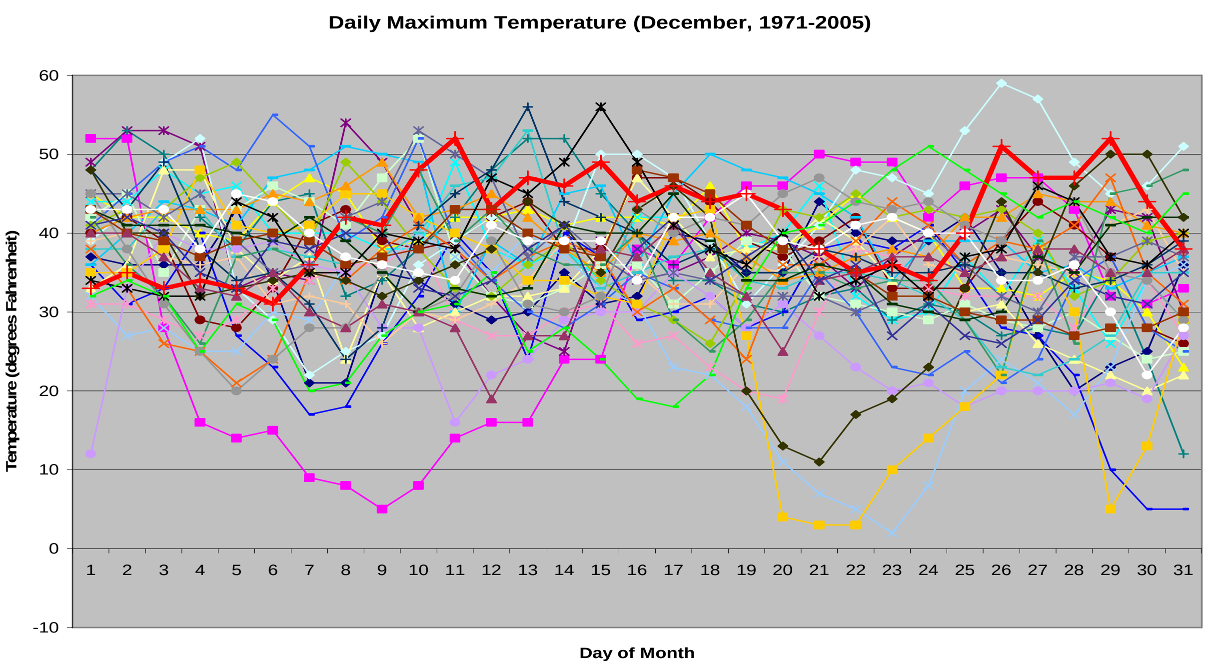

Figure 14. Daily Maximum Temperature for December from 1971-2005. Each line represents the days for a month in a single year. The highlighted red line was for the year 2004.

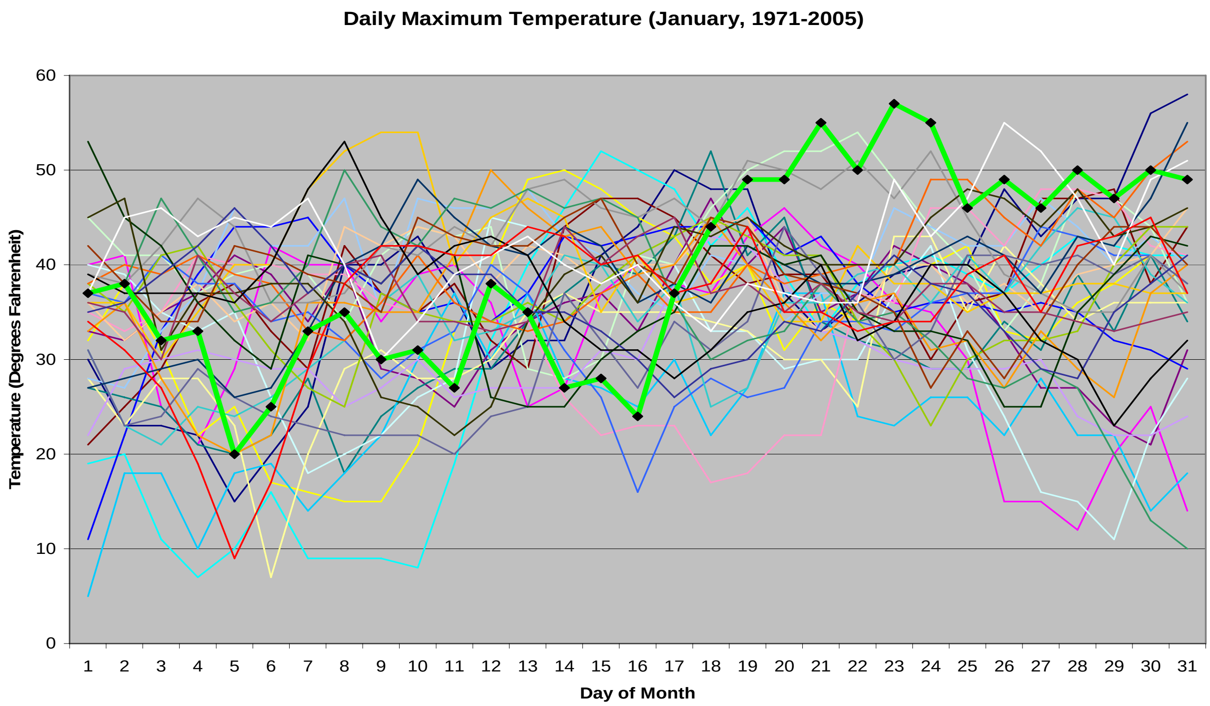

Figure 15. Daily Maximum Temperature for January from 1971-2005. Each line represents the days for a month in a single year. The highlighted green line was for the year 2005.

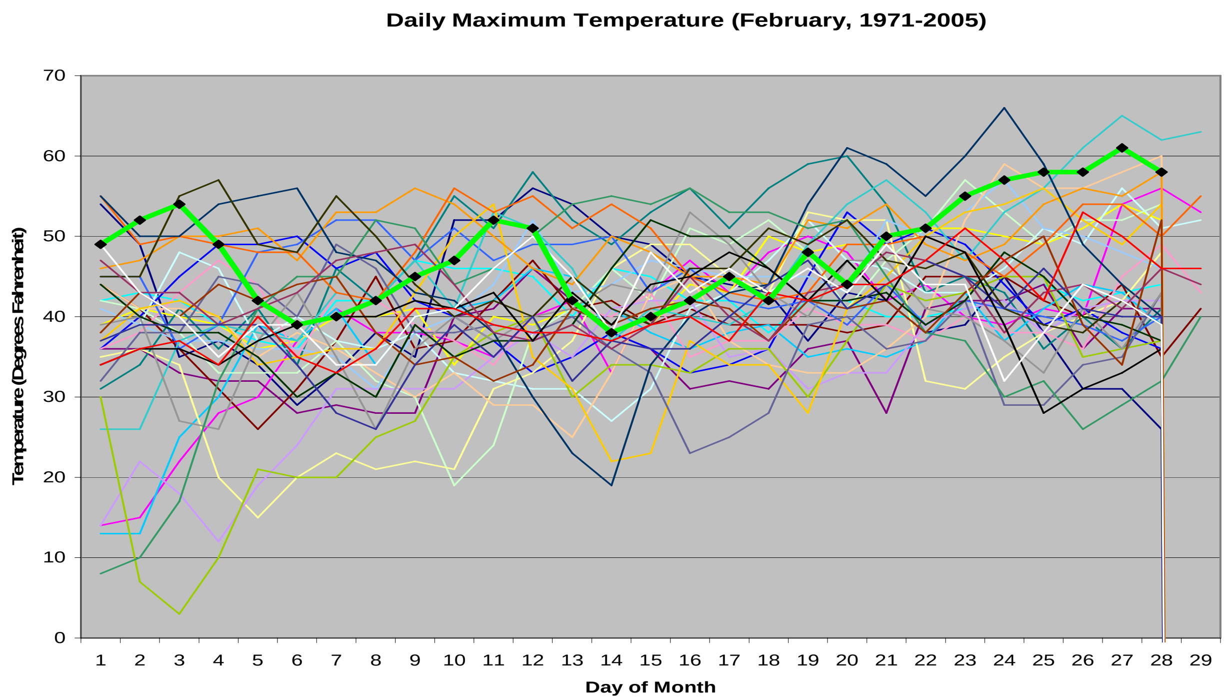

Figure 16. Daily Maximum Temperature for February from 1971-2005. Each line represents the days for a month in a single year. The highlighted green line was for the year 2005.

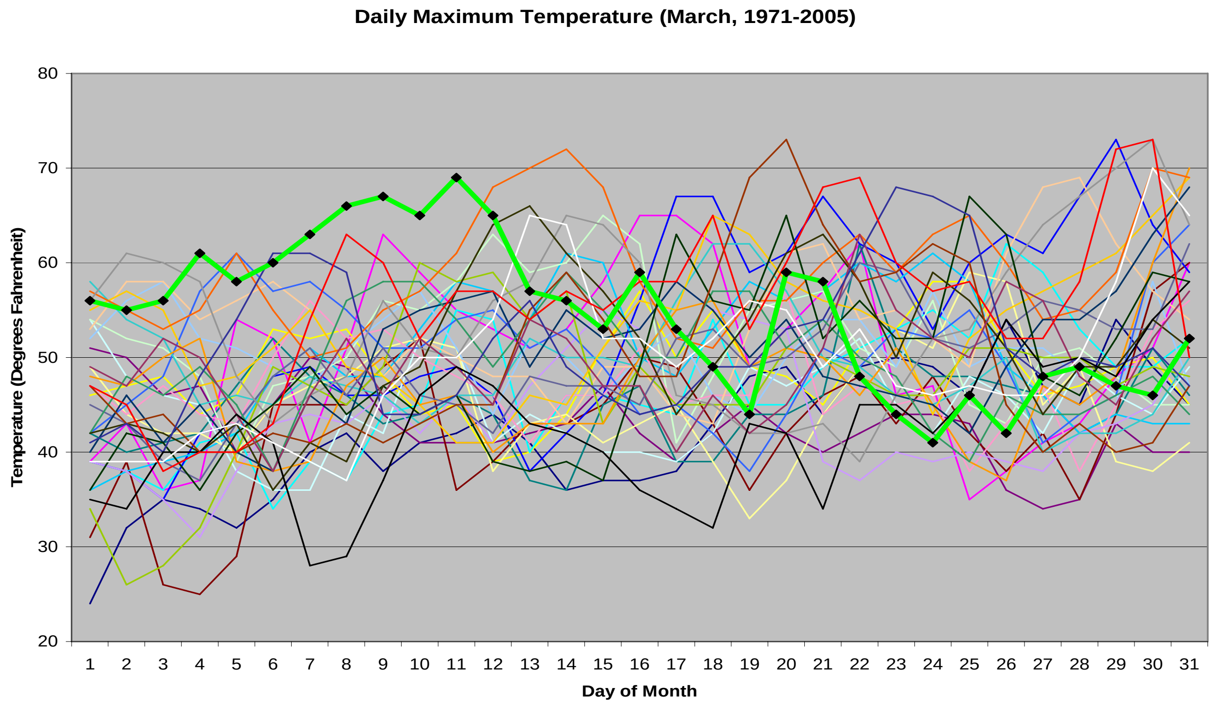

Figure 17. Daily Maximum Temperature for March from 1971-2005. Each line represents the days for a month in a single year. The highlighted green line was for the year 2005.

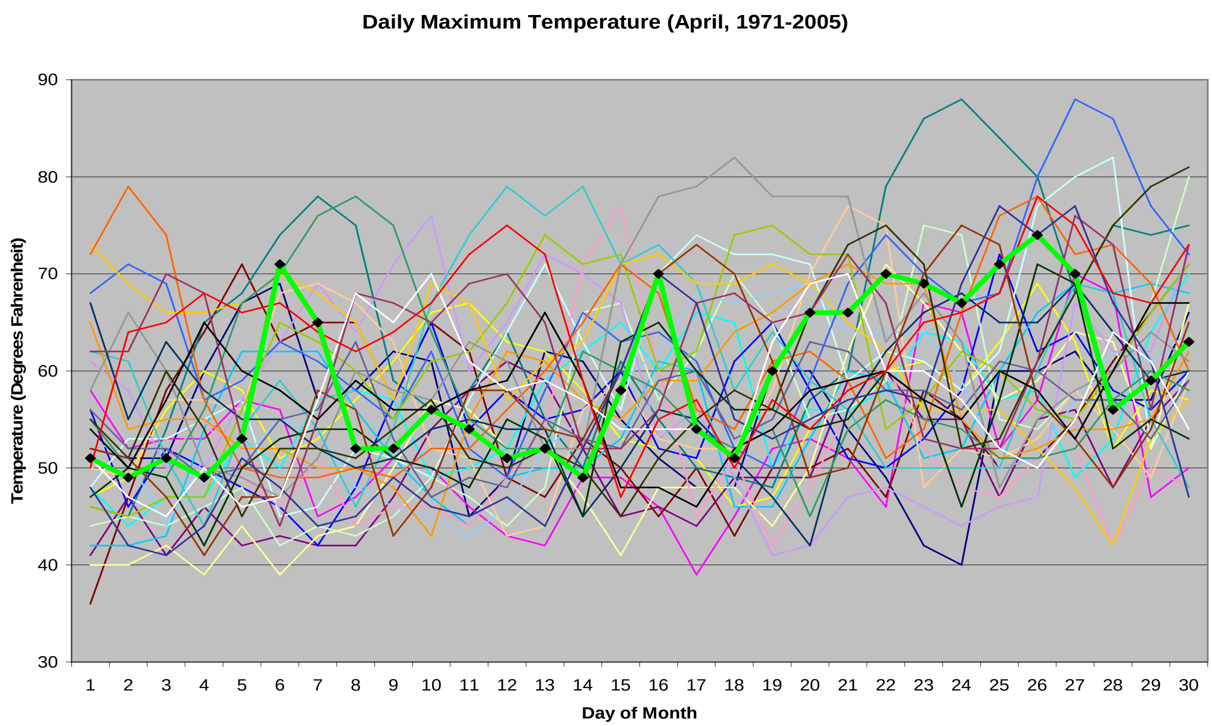

Figure 18. Daily Maximum Temperature for April from 1971-2005. Each line represents the days for a month in a single year. The highlighted green line was for the year 2005.

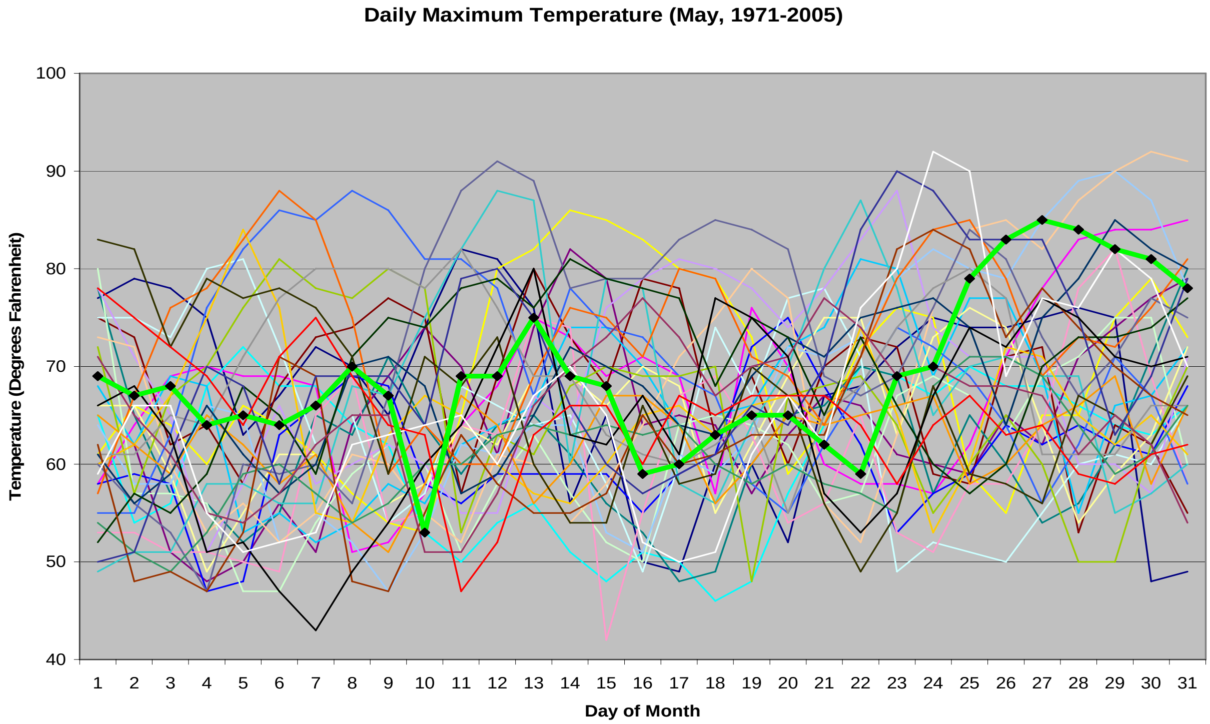

Figure 19. Daily Maximum Temperature for May from 1971-2005. Each line represents the days for a month in a single year. The highlighted green line was for the year 2005.

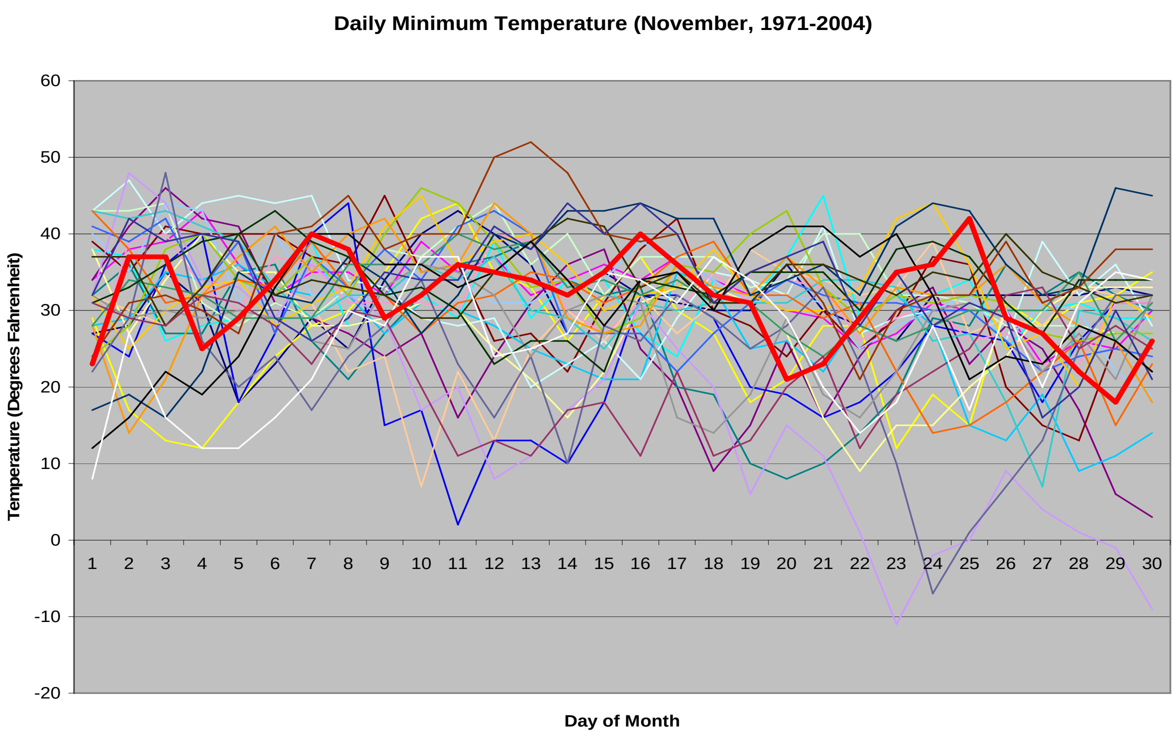

Figure 20. Daily Minimum Temperature for November from 1971-2005. Each line represents the days for a month in a single year. The highlighted red line was for the year 2005.

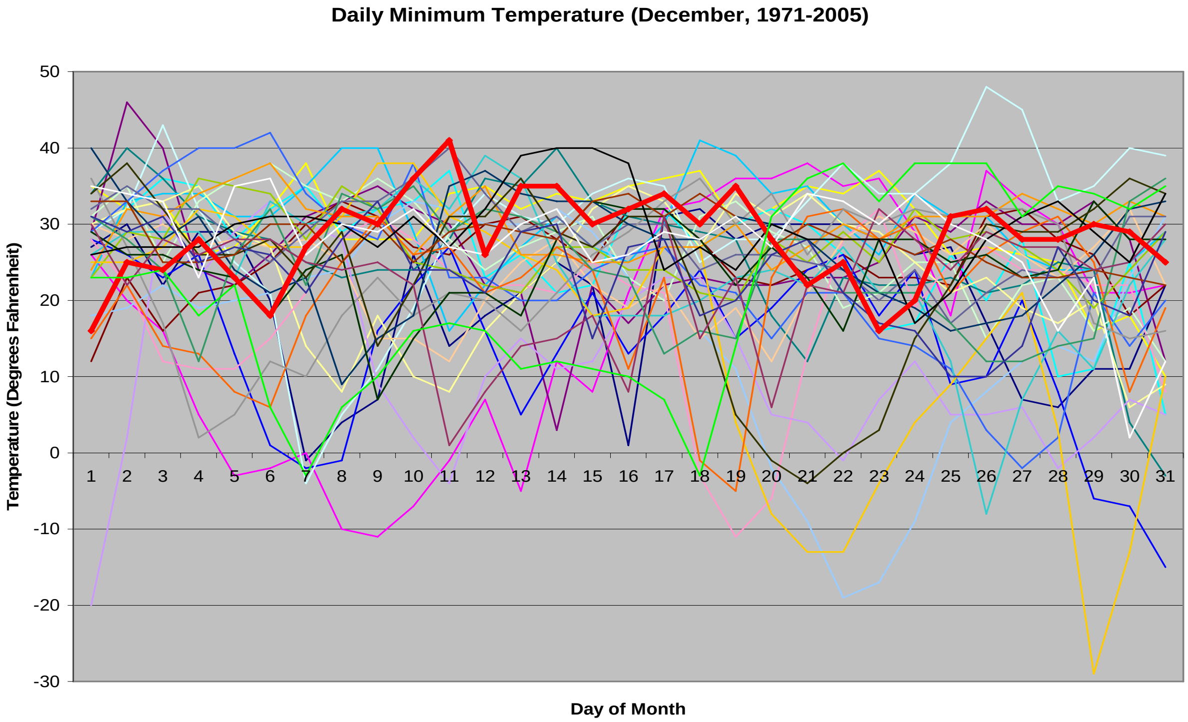

Figure 21. Daily Minimum Temperature for December from 1971-2005. Each line represents the days for a month in a single year. The highlighted red line was for the year 2005.

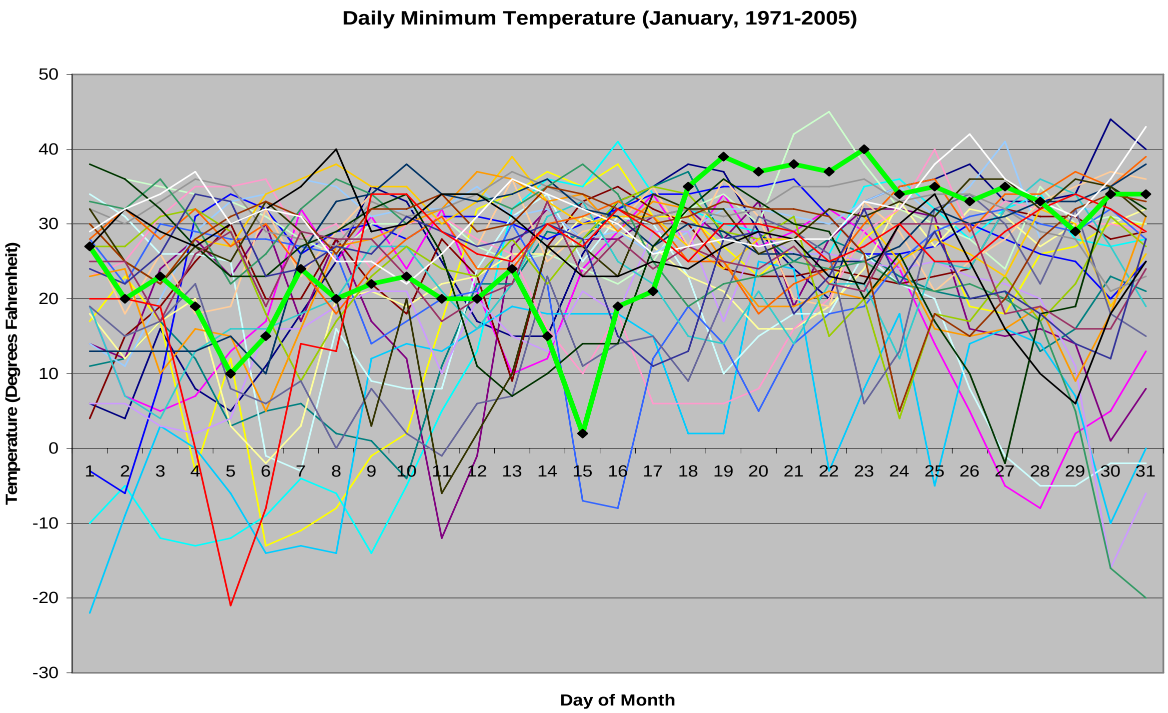

Figure 22. Daily Minimum Temperature for January from 1971-2005. Each line represents the days for a month in a single year. The highlighted green line was for the year 2005.

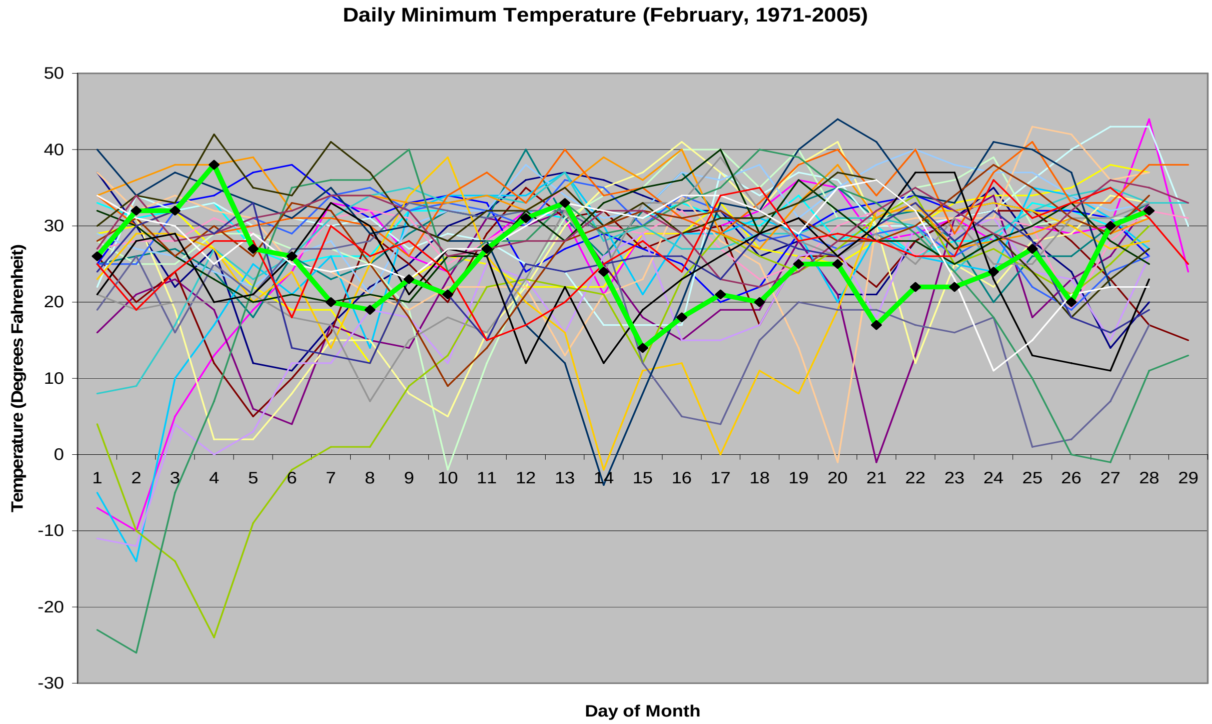

Figure 23. Daily Minimum Temperature for February from 1971-2005. Each line represents the days for a month in a single year. The highlighted green line was for the year 2005.

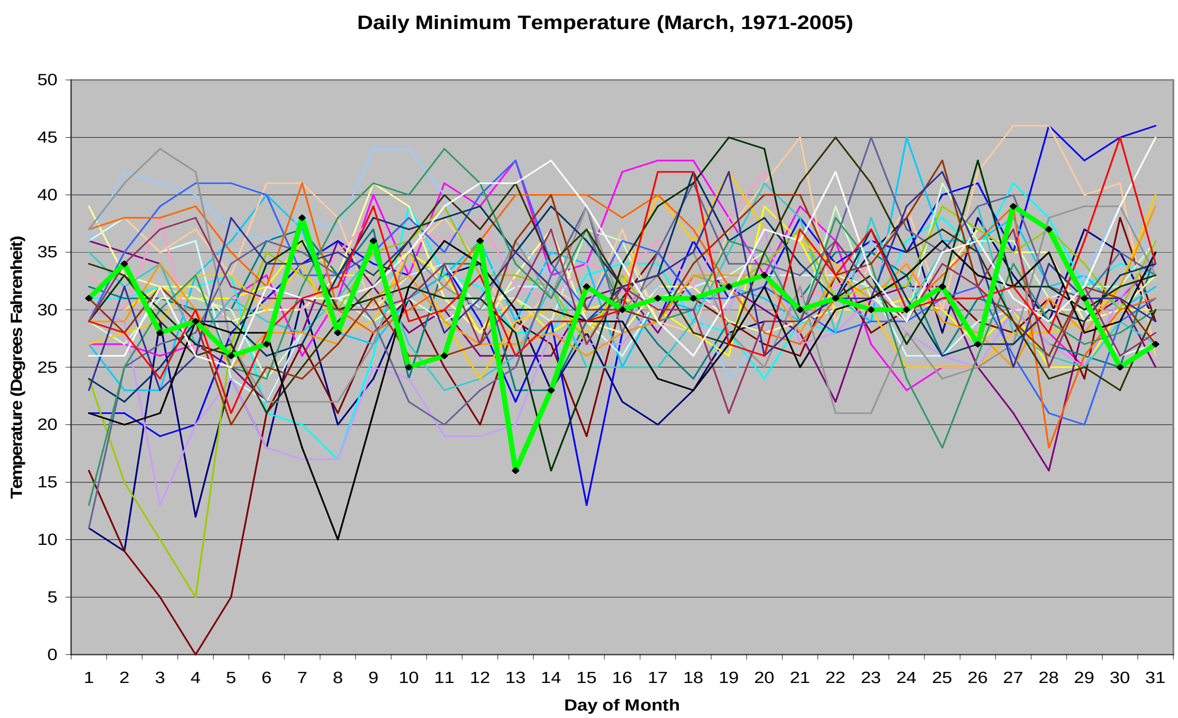

Figure 24. Daily Minimum Temperature for March from 1971-2005. Each line represents the days for a month in a single year. The highlighted green line was for the year 2005.

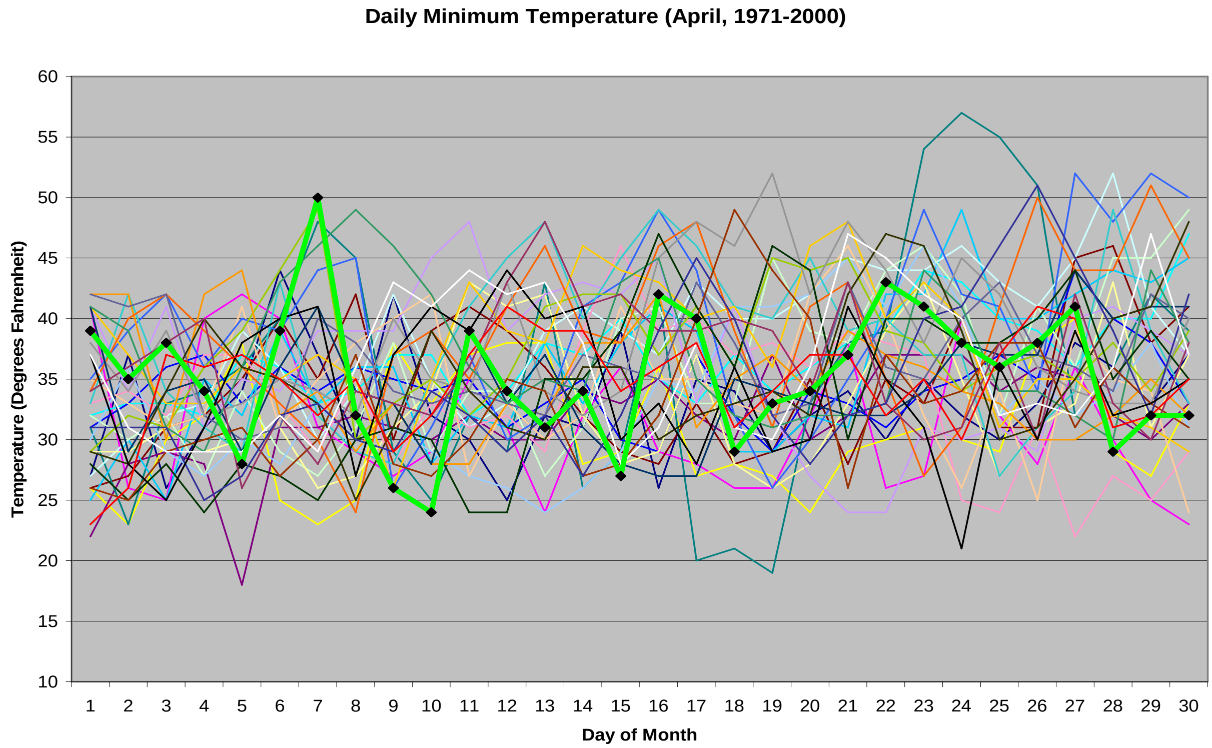

Figure 25. Daily Minimum Temperature for April from 1971-2005. Each line represents the days for a month in a single year. The highlighted green line was for the year 2005.

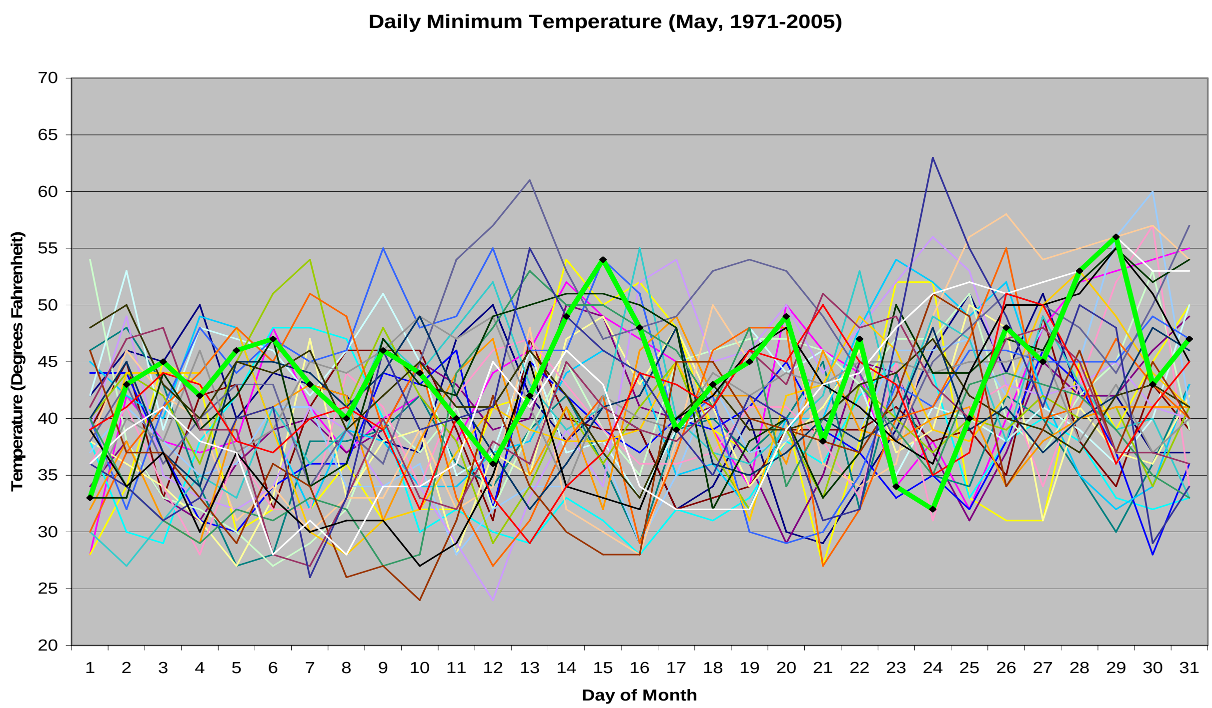

Figure 26. Daily Minimum Temperature for May from 1971-2005. Each line represents the days for a month in a single year. The highlighted green line was for the year 2005.

The data for each month over the 35 year period 1971-2005 can be ranked in order to calculate exceedance probabilities associated with the mean values of maximum temperature and minimum temperature actually obtained each month. Tables T1 and T2 show these exceedance probabilities by month for maximum temperature and minimum temperature, respectively.

Table T1. Exceedance probabilities for the monthly average of the maximum daily temperatures with respect to the 1971-2005 historical period.

Month	Tmax (Deg F)	35-Year Median Tmax	Rank	Exc. Prob. (%)	Return Period (Years)
Nov '04	44.9	43.3	14	39	2.6
Dec '04	35.1	35.6	24	67	1.5
Jan '05	39.5	36.1	7	19	5.3
Feb '05	48.3	41.0	3	7	13.4
Mar '05	54.6	49.5	3	7	13.4
Apr '05	59.3	57.0	11	30	3.3
May '05	69.3	66.2	5.5	15	6.9

Table T2. Exceedance probabilities for the monthly average of the minimum daily temperatures.

Month	Tmin (Deg F)	35-Year Median Tmin	Rank	Exc. Prob. (%)	Return Period (Years)
Nov '04	31.4	31.4	18	50	2
Dec '04	28.1	24.1	7	19	5.3
Jan '05	26.4	24.2	12	33	3
Feb '05	24.9	27.4	23	64	1.5
Mar '05	30.0	31.2	29	81	1.2
Apr '05	35.2	35.2	18	50	2
May '05	43.8	40.7	3.5	9	11.8

In Tables T1 and T2, the rank is the placement of the particular month's temperature in the 35 year record. The largest monthly average has a rank of one, and the smallest value has a rank of 35. The exceedance probabilities correspond to the likelihood in any given year of observing a value of the average maximum or minimum temperature that was greater than the value actually experienced. Low exceedance probabilities indicate that one is unlikely to observe a value as large or larger as that actually observed; the larger the exceedance probability, the more likely it is for that value or larger to be observed. The large amount of variability of temperature within each month, as shown in the daily maximum and minimum temperature figures, causes them *to have a large standard deviation, which creates some uncertainty in the ranking of each value with respect to the values from other years. This in turn produces some uncertainty in the actual values of the exceedance probabilities.*

Precipitation
Cumulative monthly precipitation depth is the sum of the depths of all precipitation events, including frozen (i.e., snow or ice) and liquid precipitation, all reported in terms of their melted liquid depth. As with other meteorological variables, there is a large amount of variability across the years both within a specified month, and between months. The range of values over the 35 years for precipitation from November through May includes values close to or less than half an inch in every month except November, and values in excess of five inches in every month as well. The time series of monthly precipitation depths are shown in Figures 27 to 33 with each month collected in a single figure and displayed sequentially by year.

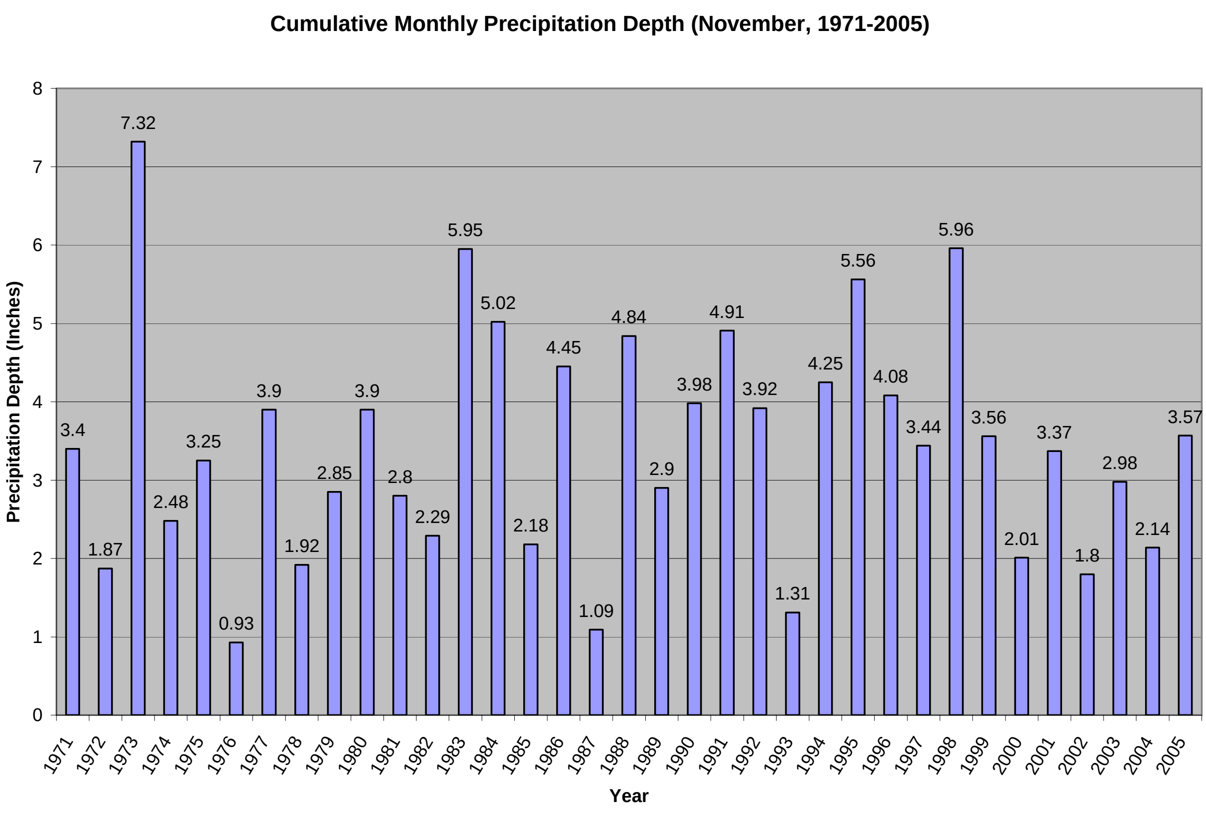

Figure 27. Cumulative Monthly Precipitation Depth for November (1971-2005).

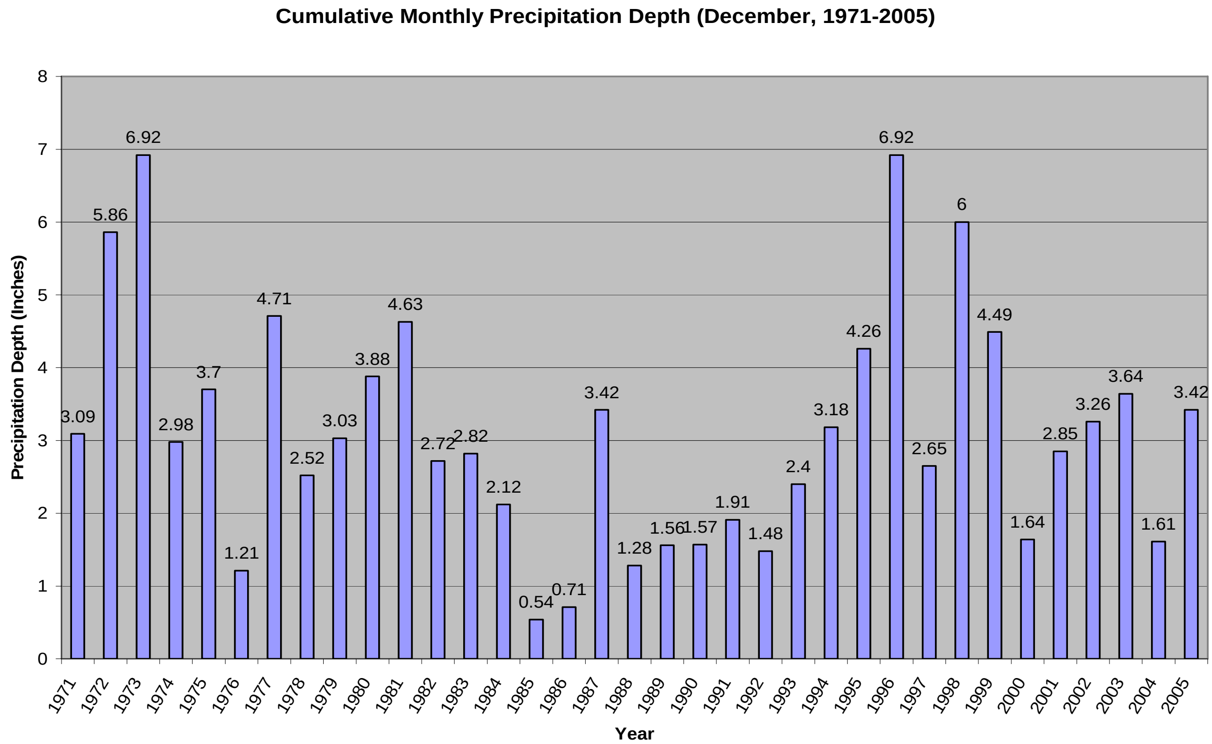

Figure 28. Cumulative Monthly Precipitation Depth for December (1971-2005).

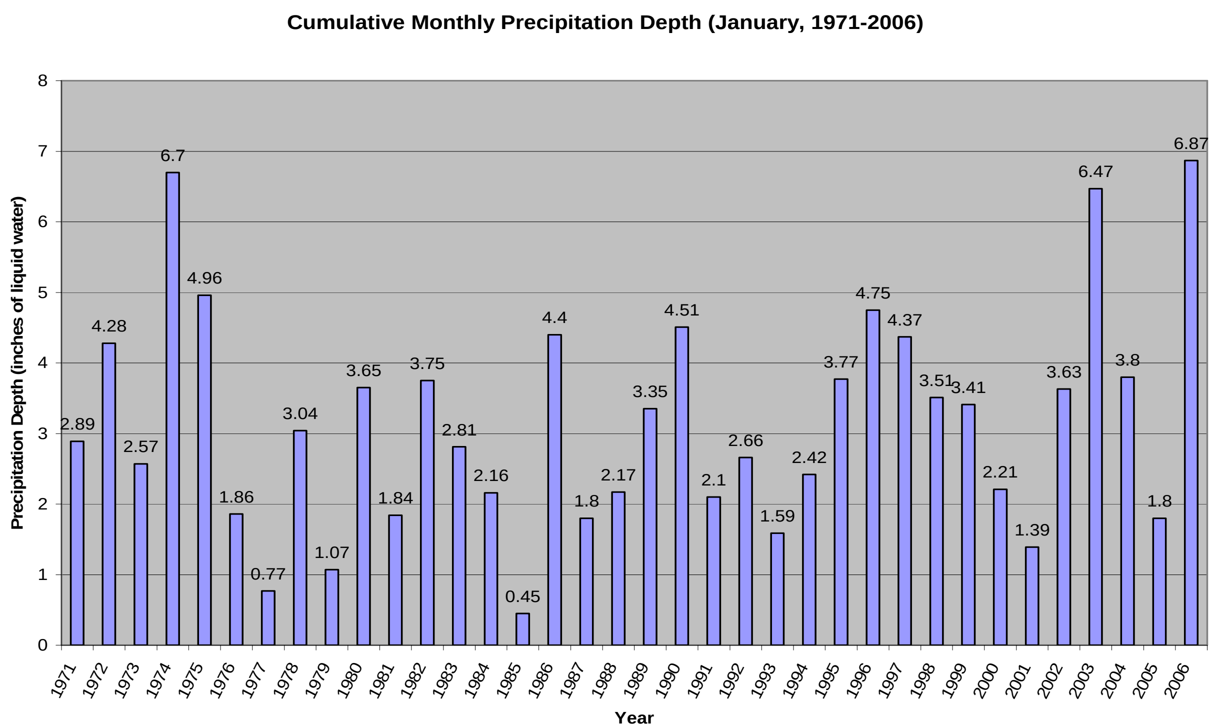

Figure 29. Cumulative Monthly Precipitation Depth for January (1971-2006).

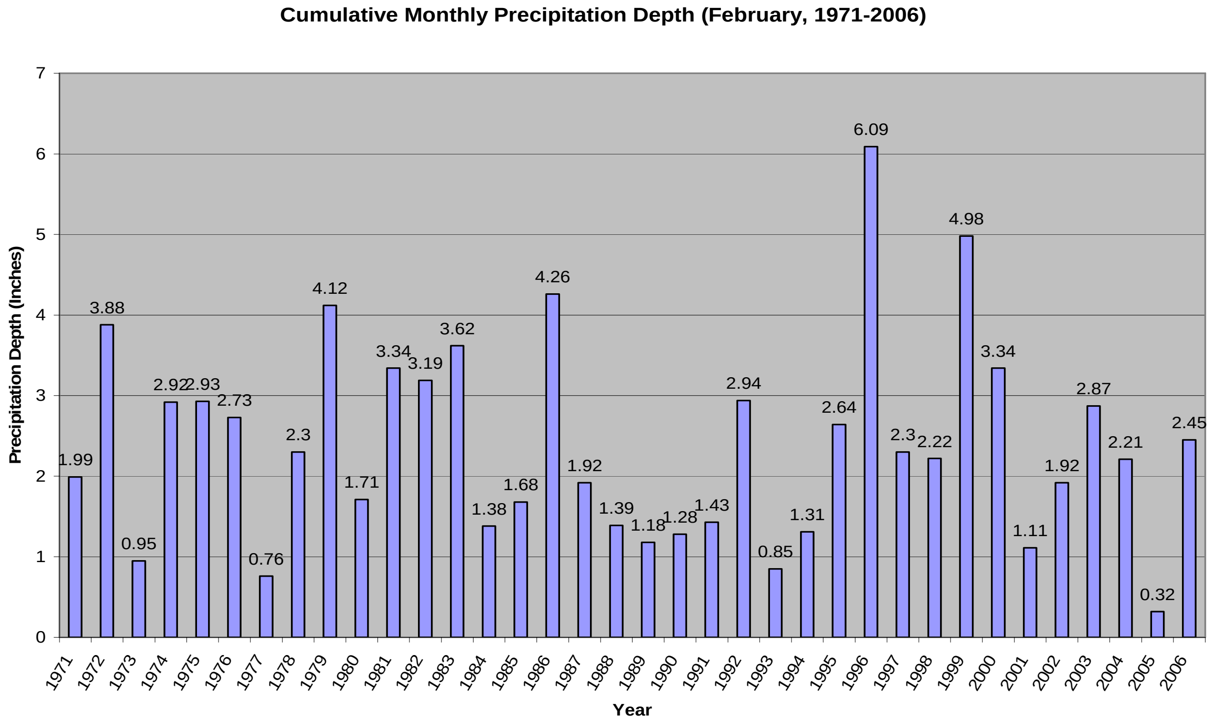

Figure 30. Cumulative Monthly Precipitation Depth for February (1971-2006).

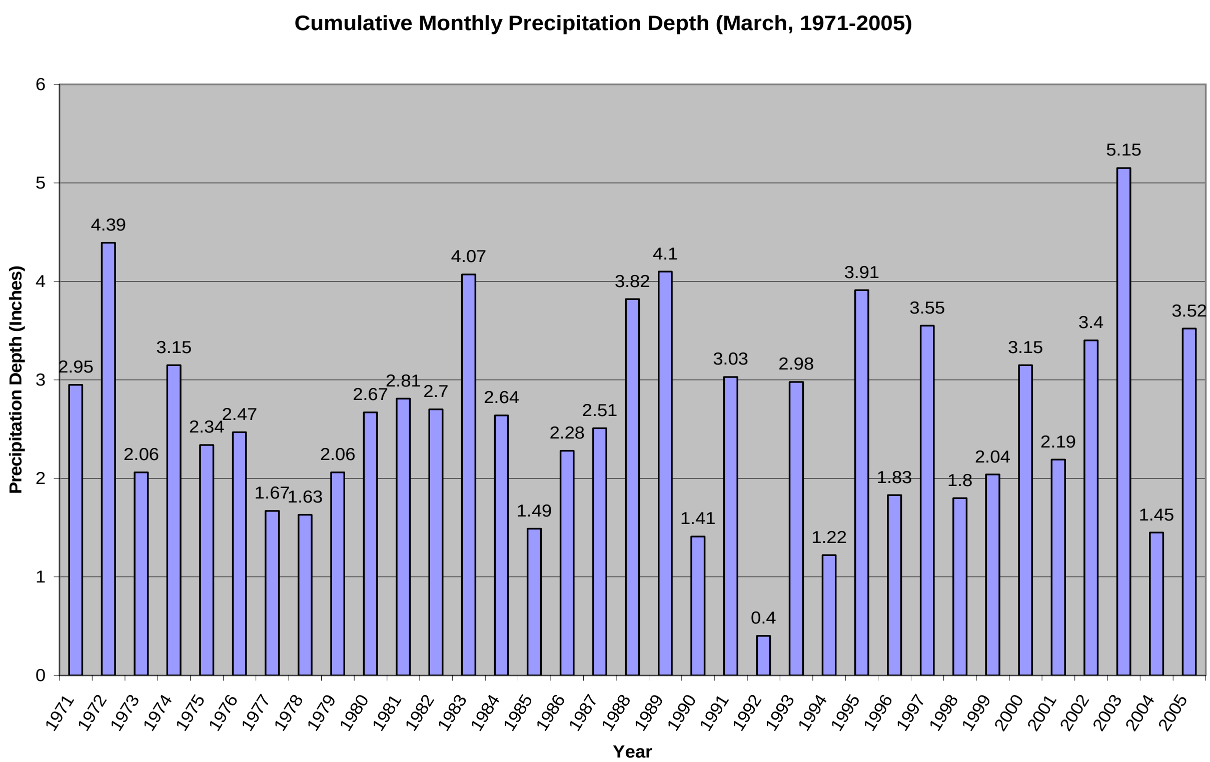

Figure 31. Cumulative Monthly Precipitation Depth for March (1971-2005).

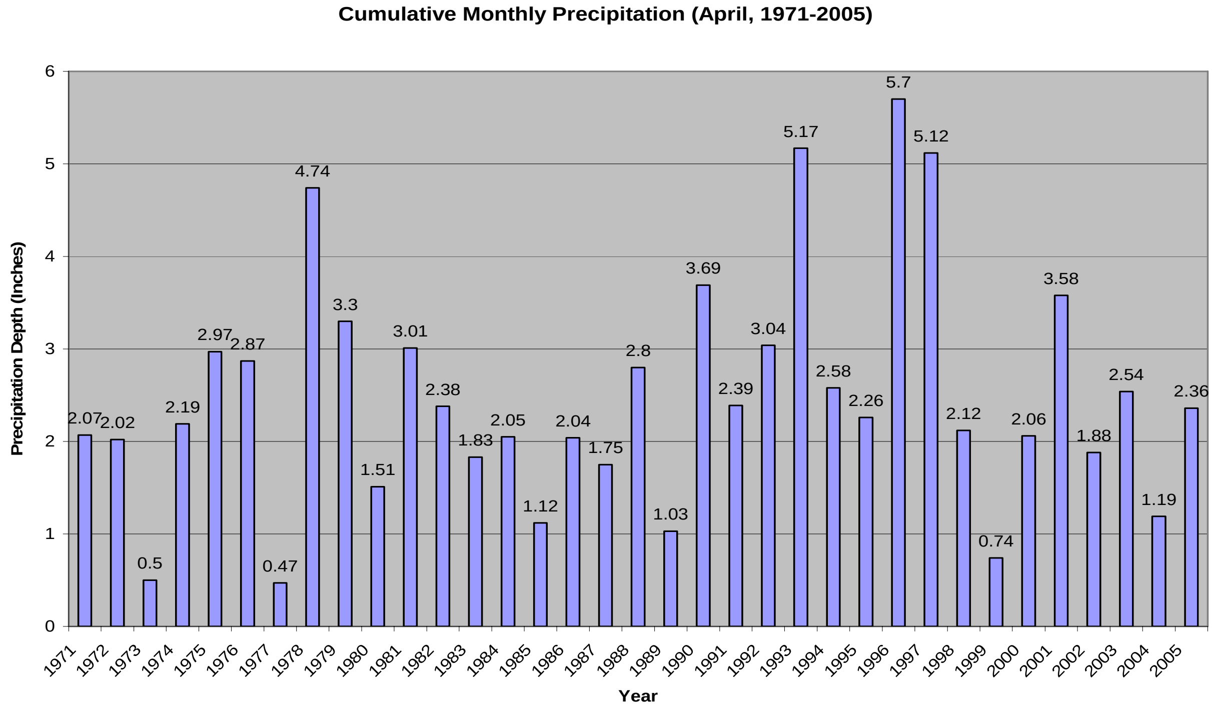

Figure 32. Cumulative Monthly Precipitation Depth for April (1971-2005).

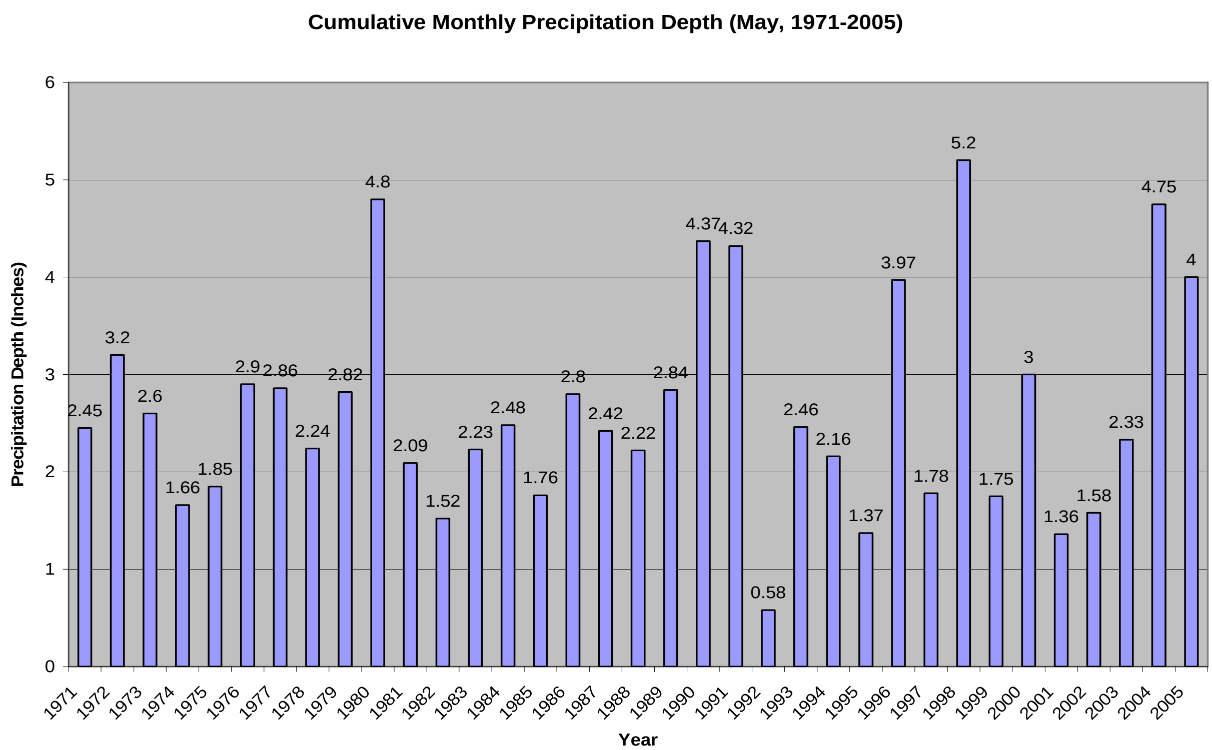

Figure 33. Cumulative Monthly Precipitation Depth for May (1971-2005).

The data for each month over the 35 year period 1971-2005 can be ranked in order to calculate exceedance probabilities associated with the values of cumulative monthly precipitation actually obtained each month. Table P1 shows the exceedance probabilities associated with each month.

Table P1. Exceedance Probabilities for the cumulative monthly precipitation depth with respect to the 1971-2005(6) historical period.

Month	Precip (in)	Median (in)	Rank	Exc. Prob (%)	Return Period (Years)
Nov '04	2.14	3.40	28	81	1.2
Nov '05	3.57	3.40	15	44	2.3
Dec '04	1.61	2.98	28	81	1.2
Dec '05	3.42	2.98	12	33	3.0
Jan '05	1.80	2.97	30	82	1.2
Jan '06	6.87	2.97	1	2	58.
Feb '05	0.32	2.26	36	98	1.0
Feb '06	2.45	2.26	16	43	2.3
Mar '05	3.52	2.64	8	22	4.6
Apr '05	2.36	2.26	17	47	2.1
May '05	4.00	2.45	6	16	6.23

In Table P1, the rank of a particular month's precipitation is its placement with respect to the same month in the 1971-2005(6) historical period, with the largest value for the period holding the rank of one, and the smallest holding the rank of 35(36). The rank indicates how many years of the historical period that the same-month precipitation was greater than the value measured in the month represented by a particular row in the table. Values of a climatological variable falling within the middle one-third of exceedance probabilities, (i.e., having exceedance probabilities between 33% and 66%, or falling within the middle third of measured values) are often considered to represent the normal climate, and values falling above or below this range are considered to represent climate realizations above or below normal, respectively.

Considering the measurements during the study period from January 2005 through May 2005, two months, January and February, had exceedance probabilities in the upper one-third, meaning they are likely to be exceeded, and therefore are "small" relative to the climatological norm. Two months, March and May, had exceedance probabilities in the lower one-third, and therefore represented high precipitation months relative to their climatological norms. April precipitation fell almost exactly on the median, with an exceedance probability of 47%. This was squarely in the middle of the climatological norm for that month.

This wide range of observations with respect to climatological normals, made the 2005 study period nearly perfect for what we hoped to accomplish with respect to *precipitation. There were two goals: one was to establish the relative magnitudes of monthly precipitation between the three stations in the study area; the other was to establish the climatological norm for each station with respect to the long term record at the UI Plant Sciences Farm. With regard to the relative magnitudes of precipitation within the study area, the different months brought a wide range of precipitation, yet the stations maintained their same relative magnitudes. This provides a high degree of confidence that the relative magnitudes of precipitation as measured during the study period will be maintained regardless of how large the precipitation depth is during a given month. Secondly, the wide range of monthly precipitation depths observed allowed us to assess the relationship of the precipitation at each of the study sites to that at the UI Plant Sciences Farm. Had all the values fallen at or near their median values, the tight cluster of points would have made it impossible to extrapolate outside that range with any certainty. As it was, between January and May, 2005, values of monthly precipitation between 0.32 inches and 4.00 inches were observed at PSF, and there was a strong correlation between the PSF values and those in the study area, as shown in Figure 34 below, which is a reproduction of Figure 10 from the Climate Study. This gives great confidence in the relationships established between monthly precipitation at PSF and the three measurements stations in the study region, which further allows us to estimate the climatological normal values for monthly precipitation at the individual stations based on the long term record at PSF with greater confidence.*

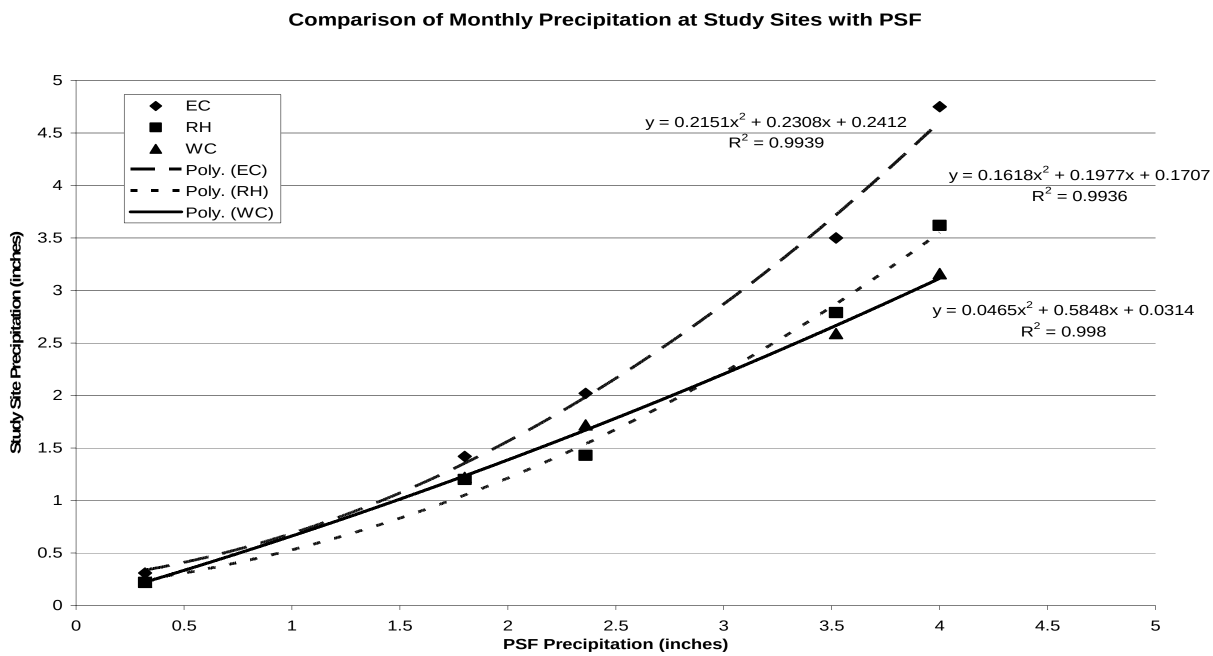

Figure 34. Monthly precipitation at each of the three study sites paired against precipitation depth at PSF for each of the corresponding months, January through May 2005 (symbols). The lines are polynomials fitted to the data from each of the study sites versus PSF. The fitted polynomial equations are shown next to their corresponding lines, as are the R-Squared values (Appears as Figure 10 in Climate Report).

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