# SOIL SURFACE TEMPERATURE DIFFERENCE BETWEEN STEEL AND HYPALON PILLOWS

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## ABSTRACT

Systematic bias in data collection systems is often difficult to identify and moreover, on a site specific basis, hard to correct. Yet, bias free data are essential for long term climatic comparisons to identify the magnitude and direction of change. Systematic bias in the SNOTEL record between steel and hypalon pillows has been identified and ranges between 0% and 25% (Julander and Bricco, 2006, Osterhuber, 1996). Observationally, the greater differences are typically at lower elevations and warmer temperatures while higher elevation, cooler sites typically have lower differences or none at all. Snow pillow data are now being used to quantify differences in SWE accumulation, initial accumulation dates and melt out dates for global climate change research. Since originally the entire SNOTEL system was installed with steel pillow and since that time many steel pillows have been replaced with hypalon, it is essential to take a second look at these parameters to insure data consistency and accurate results. Hypalon pillows are typically black and have between 100 and 200 gallons of fluid whereas steel pillows are typically covered with gravel and have about 20 gallons of fluid. Hypalon pillows could become a heat sink, absorbing energy in the summer and slowly releasing it through later periods which could impact early season snow accumulation. The black pillows might possibly increase solar energy absorption during ablation, increasing melt rates in the spring. To test this hypothesis, temperature sensors were placed under collocated hypalon and steel pillows at Parleys Summit and Trial Lake SNOTEL sites in Utah. Results indicate that there is a substantial temperature difference and that it is possible that this difference could impact snow accumulation and ablation. This impact needs to be recognized in long term comparisons of all aspects of snow data analysis.


## INTRODUCTION

The Natural Resources Conservation Service, formerly the Soil Conservation Service began the manual standardized collection of snow data in the early 1930s. In the late 1970's with the advent of SNOTEL, many snow courses were automated allowing for a much more robust snow data set with at least daily data. In the intervening years, the SNOTEL system has been changed in many significant ways. Most stations now collect hourly data on SWE, precipitation, temperature and snow depth. Many sites now have soil moisture and soil temperature sensors. Other changes include the addition of meterological towers and standardized heights and mounting for instrumentation. As instrumentation has improved, various sensors have been changed. A case in point is the SWE sensor or snow pillow. All SNOTEL sites in the initial installation had steel pillows. The pillow arrangement ranged from 2 to 4 steel pillows in various arrangements. Typically the 2 and 3 pillow arrangements were side by side in a row and the 4 pillow sites were arranged in a quad formation. Individual steel pillow sites had various idiosyncratic behaviors such as large data fluctuations - i.e. given hourly data steel pillows may exhibit a range of SWE values of plus or minus up to 1 to 2.5 cm daily. Adding a gravel covering helped stabilize this fluctuation at most sites. Where snow creep or snow bridging occurs, steel pillows tend to amplify that affect (Julander et. Al Franklin Basin). Hypalon pillows tend to be more stable with regard to these particular phenomena than their steel counterparts but display other unsettling characteristics, specifically they catch less snow than the steel pillows do. This is particularly important with regard to studies with long term comparisons such as Climate Change or Global Warming as this systematic bias in the data set could easily be attributed to a shift in climate when in fact it can be partially attributed to sensor change. Most Data Collection Areas (there are 6 NRCS Data Collection Areas in the western US with offices in Denver, Bozeman, Salt Lake City, Boise, Portland and Anchorage) currently have a mix of steel and hypalon pillows but some areas such as Boise and Bozeman are mostly or entirely hypalon. In the initial studies regarding pillow behavior, this SWE under-catch was attributed to the rigidity of steel pillows and edge to surface area effects. In an NRCS Idaho analysis, hypalon and steel pillows during periods of low snow were found to have some difference but this difference was proportionately higher in large snowpack years. In the higer snowpack years, there was an average difference of 13% with a maximum difference of 26% in March 1 SWE values.

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Of the 24 Idaho sites analyzed for March 1 SWE, 19 steels were higher than hypalon, 3 sites had hypalon exceeding steels and there were 2 sites that were essentially the same (Palmer, 1993). This research will try to ascertain if there is a temperature component associated with this difference in SWE accumulation.

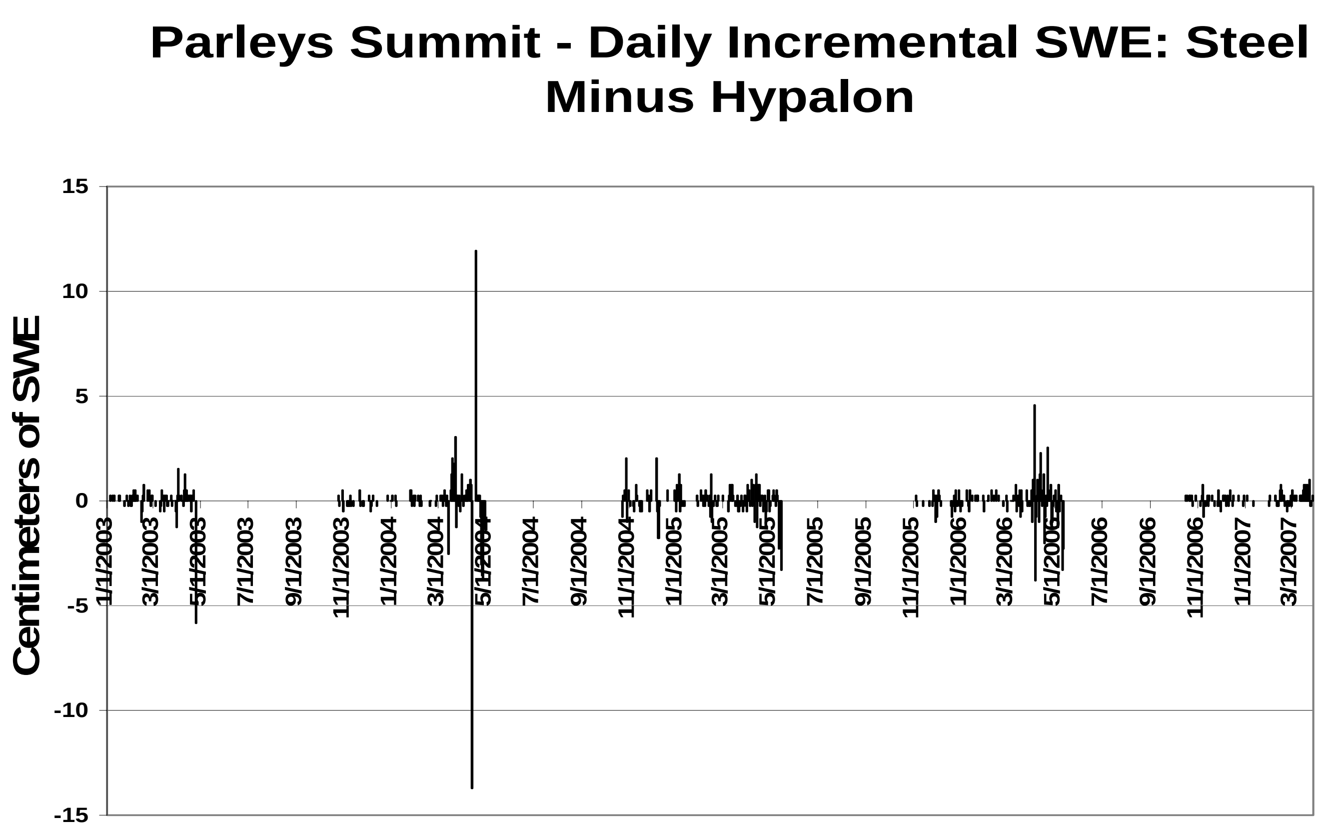
## METHODS

Colocated steel and hypalon SNOTEL data from Idaho and Utah are analyzed to show the accumulation difference between pillow systems. Manual data collected from the steel and hypalon pillows at two sites in Utah are used to confirm that there is a difference in snow accumulation at these sites strengthening the hypothesis that there may be some physical processes involved. Thermistors were installed under steel and hypalon pillows at Parley Summit and Trial Lake SNOTEL sites in Utah to compare energy balances. These will continue over the next few years and then white coverings will be placed on top of the black hypalon pillows and the energy balance re-examined. Accumulation and ablation rates were examined at Parley Summit and Trial Lake on both steel and Hypalon Pillows to document difference in pillow behavior.

## RESULTS

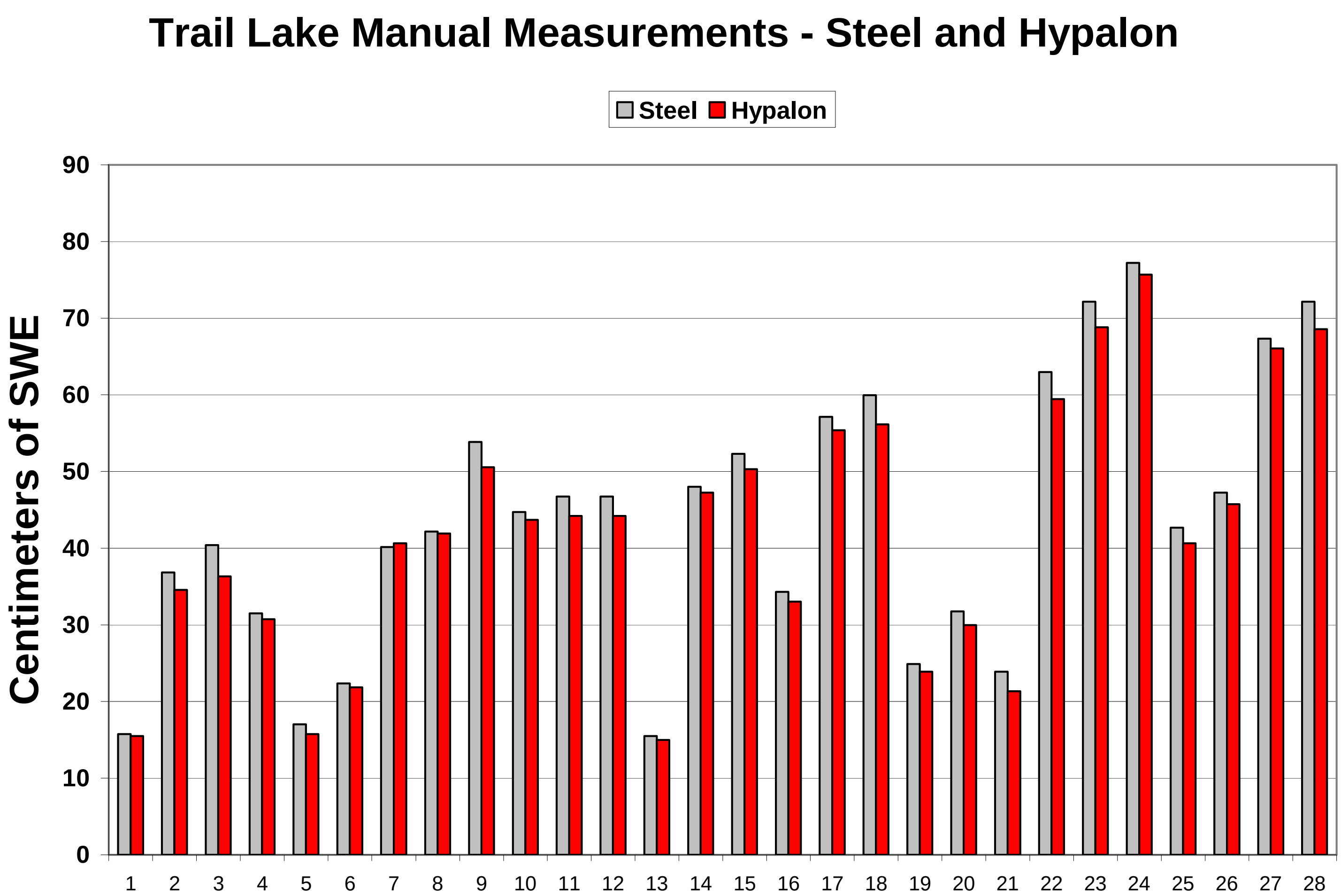
Twenty co-located steel and hypalon pillows in Idaho were analyzed for April 1 SWE data for the years 1996-2001 and the average difference was about 7% higher values for the steel pillows than for the hypalon. The average difference for all twenty sites was about 3.8 cm with a range of -6.4 to 34.3 cm of SWE. The range of difference was -32% to a positive 52% indicating that individual site characteristics play a major role in SWE accumulation over very small spatial scales. This range of years included both high and low accumulation years in the mix. In order to ascertain if there is a difference in early season SWE accumulation or late season SWE ablation, the difference between steel and hypalon daily incremental values of SWE were plotted for the Parleys Summit and Trial Lake sites in Utah. The results are somewhat nebulous in that there seems to be a more or less consistent pattern of increased SWE on the steel pillows throughout the accumulation season as well as what appears to be accelerated melt on steel pillows during the ablation period. Caution should be exercised in evaluating these results as noise in the sensor system could be a factor as well as the sensors accuracy in resolving accumulations of a centimeter or less.

Chart 1.



The difference in meltout dates for this site ranged from both pillows melting out on the same day to the steel pillow melting out 17 days later than the hypalon. The Trial Lake incremental difference between steel and hypalon pillows looks very much the same as the Parleys Summit data showing the same noise of sometimes steel exceeding hypalon and vice versa as well as the apparent acceleration of melt on the steel pillows during the later season. The very latter part of that acceleration is partly due to the hypalon pillow becoming free of snow earlier than the steels. For Trial Lake, the hypalon pillow melted out between 0 and 13 days earlier than the steel pillows. At Trial Lake, the manual measurements taken at each corner of the steel and hypalon pillows are compared in chart 2. These measurements show that there is physically more snow accumulated at the steel than at the hypalon pillow.

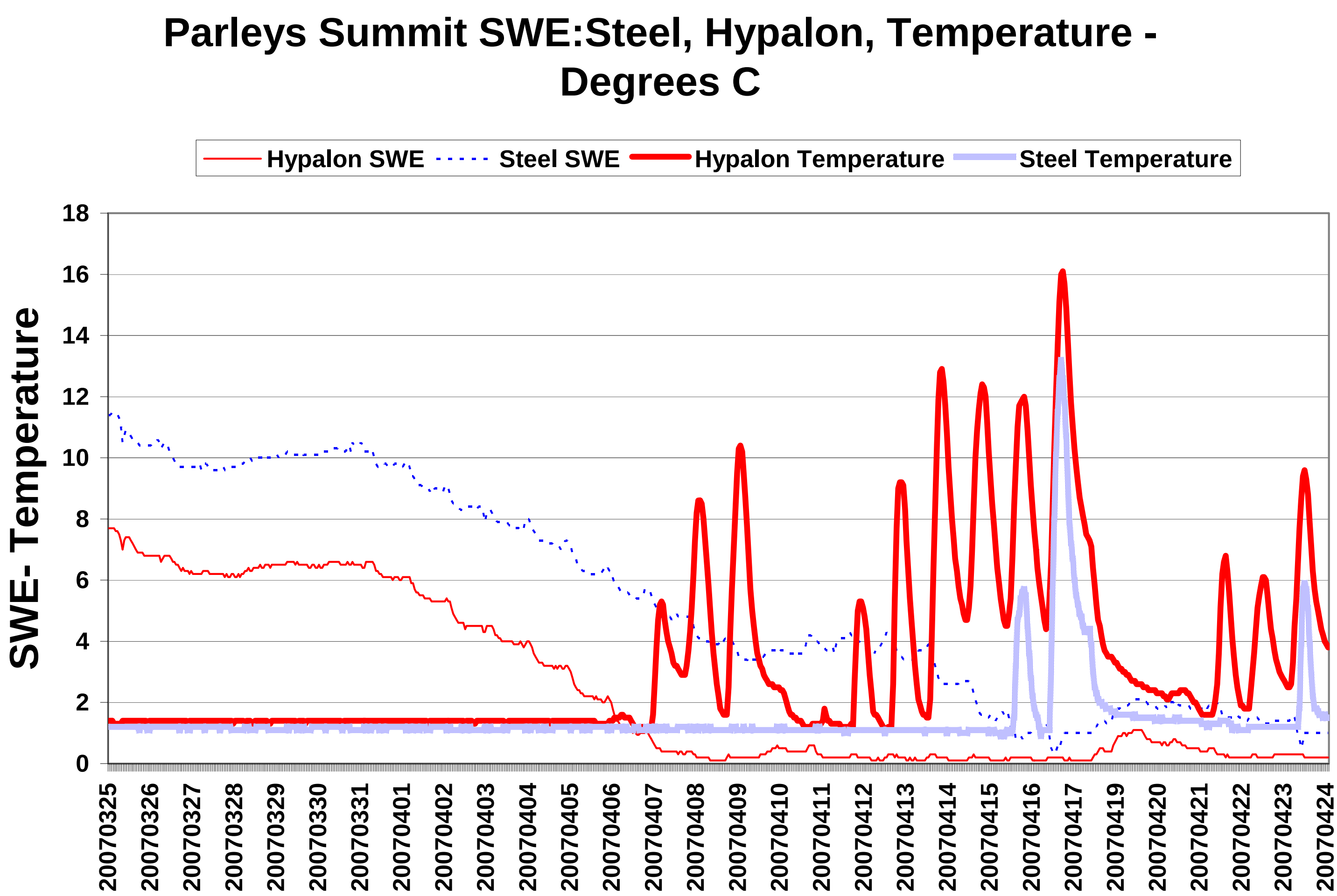
Chart 2.




The same manual measurements at the Parleys Summit site are similar showing that, according to both the electronic and the manual measurements, there is more snow on the steel pillows than on the hypalon thus not all the difference between steel and hypalon pillows can be attributed to sensor characteristics. In addition to this, the hypalon pillow at Trial Lake melts out on average 2.5 days earlier than does the steel pillow with a range of 0 to 13 days over the period of record. The steel pillow has never melted out earlier than the hypalon at Trial Lake though on 4 occasions it has melted out on the same day. This tendency persists at other sites as well and should be noted in long term comparisons of sites where steel pillows have been replaced by hypalon. Accumulation dates are far more ambiguous showing that there is only a 0.5 day difference between the beginning of snow accumulation on steel and hypalon pillows at Trial Lake. However, there is also a slight (.25 cm) greater amount of accumulation on the steel versus the hypalon, indicating the possibility that the warmer hypalon pillows may melt some early accumulation of snow. In fact, looking at small, early and late season transient storms, hypalon pillows typically melt 2 to 3 cm of SWE in 1 or 2 days whereas the steel pillows either begin accumulation or take several days longer to melt the accumulation indicating that pillow temperature may play a role in this discrepancy.

In chart 3, the SWE and the temperature of both hypalon and steel pillows are plotted for Parleys Summit for the meltout period of 2007. Note that the temperature increase of the pillows correlates exactly with the melt out of SWE on both pillows. The temperature response is very rapid with the hypalon pillow going to nearly 11 degrees C within 3 days of meltout with the same rapid response being observed at the meltout of the steel pillows. The hypalon pillow melts out 10 full days prior to the meltout of the steel pillow, during which time, the average temperature of the hypalon pillow reaches 8 degrees C. Three days after meltout on the steel pillows, there is a small storm event which brings an inch or so SWE to both pillows. The temperature sensors on both pillows decrease to relatively low levels but the hypalon responds quickly after the event, the snow melts and temperatures spike back to 6 or more degrees C nearly 3 days earlier than the steel pillows. The hypalon pillow is consistently warmer than the steel pillow and accumulates about 25% more degree day energy over the short period of observation time at both Trial Lake and Parleys Summit. These have not yet gone through a full annual cycle for analysis. Soil temperature probes installed confirm that the steel pillow temperature sensor is closer to what the more natural soil temperature is at the Parleys Summit site.

Chart 3.




This again suggests that the temperature of the pillows may play some role in both the accumulation and the ablation of the snowpack. It could also explain why observationally, the difference between steel and hypalon pillows is greater at lower elevations than at higher elevations. The steel and hypalon pillows at a very high elevation site, Lakefork Basin, 3380 meters, show no difference in SWE accumulation.

In the early 1980's at the Parleys Summit site, an additional set of steel pillows were installed (giving a primary or original set of steels and a secondary set of steel pillows) and this dual set was run until the early 1990's when the primary steel pillows were replaced by a hypalon pillow. During the dual steel pillow years, the primary set of steel pillows consistently accumulated greater SWE than did the secondary set of steel pillows indicating some physical site characteristics that favor accumulation on the primary pillow. The difference was proportionately greater at higher SWE levels (10% - 15%) and during low snowpack years, the total difference was small (5%). After the replacement of the primary steel pillows with a hypalon pillow, the secondary steel pillows have consistently higher SWE than the primary hypalon which is in the exact same favored SWE location as the originally higher reading primary steel pillows. This again indicates that there is a physical and likely temperature associated component of hypalon pillows catching less SWE than steel pillows.

## CONCLUSIONS

There are significant differences in the behavior of steel and hypalon pillows. From a climate analysis perspective, the most important of these differences are: 1) steel pillows accumulate more snow than do collocated hypalon pillows, or more importantly for long term climate research, there is an under-catch bias in the SNOTEL data set of almost all sites that have had steel pillows replaced by a hypalon pillow. This bias is significant and can be as much as 25%. 2) Hypalon pillows have a bias to melt out earlier than their steel counterpart, in some cases as much as 10 to 13 days earlier. It is unclear at this point if this can be solely attributed to the difference in SWE accumulation or if there is a physical component associated with temperature. This again, is a significant bias that must be dealt with when doing long term climate research comparisons particularly for those studies that show a trend toward snowpacks melting earlier in the season. This will have to be done on a site by site basis. 3) There could be some bias in hypalon pillows accumulating snow later in the season and in smaller initial quantities compared to steel pillows although this is not nearly as clear at this point and needs more research. It is clear that pillow temperature can play a role in the accumulation and melting of snow on those surfaces as demonstrated in post melt out snow storms. This could also be the case in early season accumulation where small storms with relatively shallow snowpacks could be melted by hypalon pillows yet retained by their steel counterparts.

## REFERENCES

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