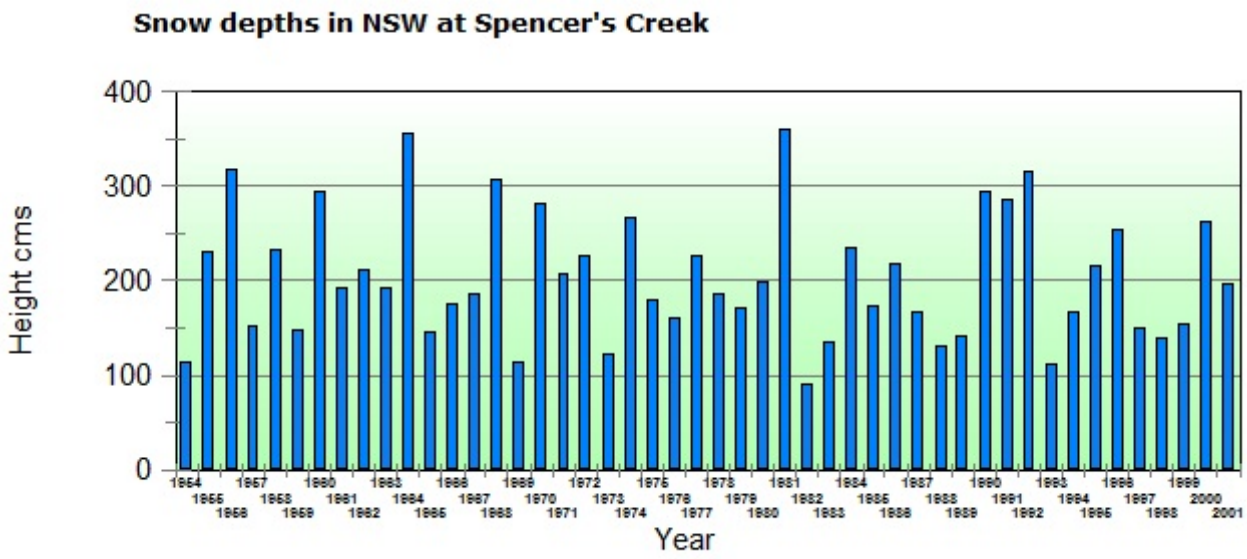
Snow depth declining in the Snowy Mountains?

The Snowy Mountains Authority (SMA) has measured the snow depth in the Snowy Mountains since 1954. Charts displaying this data are available at service stations, snow sports shops and tourist centres in the Snowy Mountains area.

The charts display the depth of snow for each month as well as the maximum depth for each year.

The snow depth is measured at Spencer's creek which is between Perisher Valley and Charlottes Pass, at an altitude of some 1,800 metres.



The above chart displays the maximum snow depth for each year from 1954 to 2001 at Spencer's creek.

The maximum depths recorded display a wide degree of variation. The descriptive statistics for the data are:

The average depth recorded was 216.8 cm and the median depth was 202.3. From the chart it is obvious that the extent of variation is quite high. Statistical measures that measure variation verify this observation. The standard deviation is 61.6cms or 28.4 per cent of the average. The range from the highest to lowest is 225.3 cms.

It is difficult to discern any trend by looking at the chart. The large year to year variations suggest that any trend either up or down is being overwhelmed by other fluctuations. Of course weather patterns are complex and are determined by many factors, including El Nino events. Snow falls depend on precipitation as well as cold air masses. Poor snowfalls are not always associated with drought conditions.

A linear trend of the data in the above chart found that there was no significant trend in a statistical sense. The trend equation was in the form:

$Y = A + BX$

where Y is the estimated trend value, A is the constant, B is the coefficient and X is time measured in Years. The suitability of such equations can be measured by the R square which

measure how much of the variation is explained by trend and the t test of the coefficient which measures whether the coefficient is actually different from zero.

The trend equation from the data was:

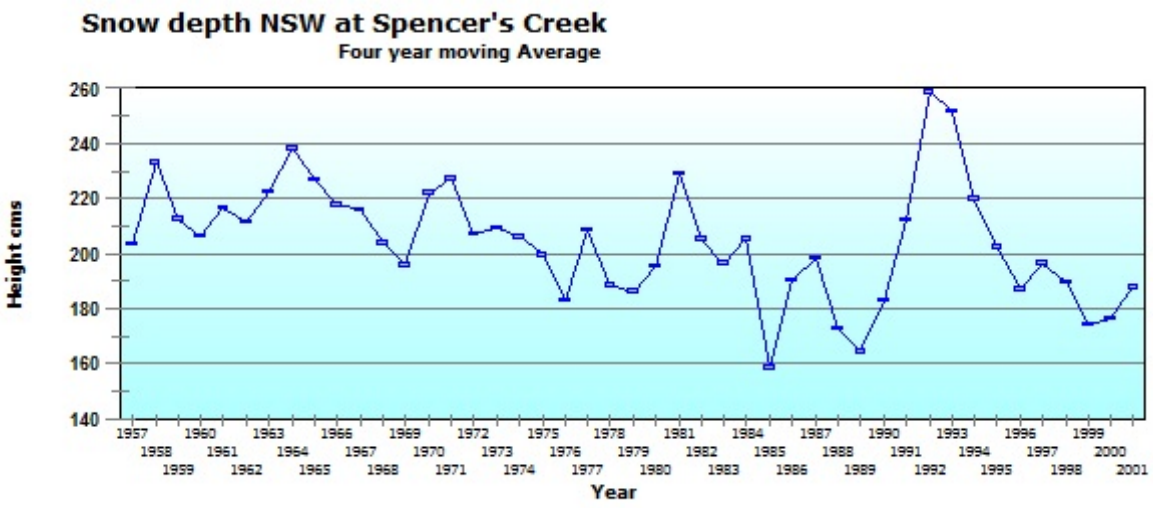
Trend = 213.96 - 0.41Year. R square = 0.01
(0.70)

t test of coefficient = -0.58

In this case the R square is extremely low and the t test suggests that the coefficient is not significant. Therefore, there is no measurable trend; although the coefficient is negative which hints at a negative trend.

However, it is possible to clarify trends and variations by using the moving average technique.

By looking at the chart it would appear that over four years each possible outcome occurs (for example below average, above average, average). Therefore a four year moving average may provide a clearer view of any trend.



From this chart it is possible to discern a downwards trend, especially from 1957 to 1989. It then goes up dramatically for about four years before resuming a downwards path. The peak in the period from 1990 to 1994 reflects the unusual period of 1990, 1991 and 1992 when high snow depths were recorded for three consecutive years. Such good snow years have been attributed to global cooling brought about by the eruption of Mount Pinatubo in the Philippines in 1991.

A linear trend equation fitted to this data resulted in the following:

Trend = 218.5 - 0.62Year R square = 0.15
(0.23)

t test = -2.73

In this equation the R square, while still low, is much higher than that of the previous equation and the coefficient is significant which means that there is a definite trend, a negative trend.

It should be noted that this trend only explains a very small part of the variation, 15 per cent as indicated by the R square figure. In other words 85 per cent of the variation is explained by other factors.

In order to look at this trend from a different angle the average and median snow depths were calculated for the first 15 years and the last 15 years and are reported in the table below.

Table 1: Average and median snow depths at Spencer's creek

Years	1954 to 2001	1954 to 1969	1986 to 2001
Average (mean)	203.9	216.9	200.0
Median	192.3	192.3	181.7

Snow depths in the latter period indicate a decline. Average snow depth fell by 7.8 per cent and the median by 5.5 per cent.

So what does it all mean?

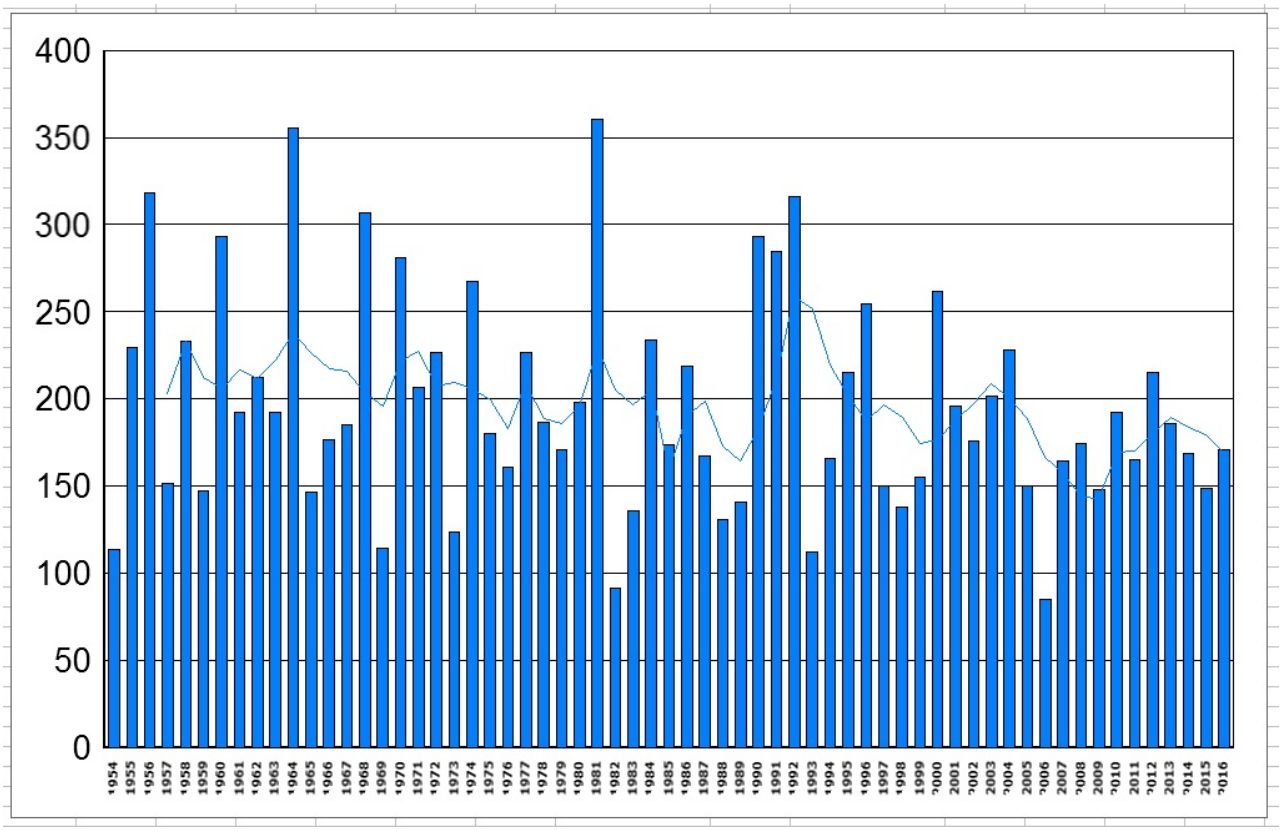
Firstly, we will be skiing for a few more years yet. The trend equation suggests that the four year moving average of snow depths will decline by 0.62 cms a year, 6.20 cms over ten years, or 62.00 cms over a century. These trend variations could be outweighed by other factors such as volcanic eruptions or other short term climatic changes. Also, the trend could change, the data only measures what happened over the last 48 years. What will happen over the next 48 may well be different.

Secondly, does it provide evidence of the Greenhouse effect and Global warming? Not necessarily, that impact is incredibly complex and could not by proved or disproved by a model as simple as this. However, it does suggest that there is some factor that is reducing snowfalls in the Snowy Mountains. Whether it is the greenhouse effect or not is a matter for research.

Thirdly, it should not be forgotten that Australia's alpine areas are marginal. With low latitudes and altitudes any snow is almost fortuitous. It would not take much variation in climate to have a large adverse impact.

Postscript - onwards to 2016

The above was completed almost a decade ago now. Since than we have the records for the thirteen years to 2013. In fact there are now 63 years of data. When the impact of global warming on Australian Alpine areas was raised by the CSIRO in the 1980s it was often said that we would not know the real impact until the first decades of the 21st century. We are well and truly there now so what has happened?



In the chart above there is evidence of further decline in the first 16 years of the 21st Century. This is made clearer by the four year moving average line. From 1954 to 1974 it was, for the most, above 200 cms, from 1974 to 1994 it hovered around 200 cms. But from 1994 to 2013 it has usually been under. It has not breached 200 cm since 2004.

Table 2: Average, median and standard deviations of snow depths at Spencer's creek (cms)

Years	1954 to 1973	1974 to 1993	1994 to 2016
Average (mean)	210.28	202.43	178.69
Median	199.4	183.25	170.5
Standard deviation	70.77	72.03	39.33

In table 2 the 63 year period is divided into thirds (the last is a bit longer) and it is evident the latest third reports both a lower mean and median than the first third covering the earlier period from 1954 to 1973. The mean for the last period is 15 per cent lower than that of the first period. However, the variation as measured by the standard deviation is much less in the more recent years.

Given that the 2016 season coincided with one of the wettest winters in Southern Australia it is surprising that the amount of snow did not reach the levels experienced in seasons such as 1981. The 3 metre level was last reached in 1992, before that in 1981, 1969, 1964 and 1956. But has not reached that level in the 24 years to 2016. Interestingly, the highest snow depth for 2016 occurred in early October, this is usually recorded in August.

It is not looking good for climate change sceptics. Since the 1980s most ski resorts in Australia have used extensive snow making which in some ways has made skiing more reliable than it was prior to its introduction. Of course snow making is not used at the Spencers Creek measurement site. Of course, snow making itself is dependent upon weather conditions, it can't be done if it is too warm.

Additionally, snow making is expensive and adds to ticket prices. I don't know why the Australian ski industry is not more supportive of efforts to combat global warming.

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