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Hydrology and Earth System Sciences Discussions



# *Interactive comment on* "Has spring snowpack declined in the Washington Cascades?" *by* P. Mote et al.

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Overall, my reaction to the conclusion that there is a 15-35% reduction in snowpack since mid-century, with an unknown portion of that resulting from natural variations, sounds more reasonable than what some local politicians in Washington state were stating recently, so I think this is moving in the right direction. I do have several questions and comments.

1) Why use a range (15-35%) for your overall conclusion? This only invites less objective people to latch on to the higher number (and they undoubtedly will), when in fact it is unrepresentative of the overall situation. The long-term VIC simulation gives -16%, and the observations from the mid 1940s give -18.6%. So it seems that a number in the upper teens is reasonable for the overall snowpack decline, with some statement



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of uncertainty.

2) I know it's not your fault that the snowcourse data are only reliable from mid-century to present, but it is still bothersome to me that this is the period used for the analysis—starting near the beginning of a negative PDO regime, and ending near the end of the following positive PDO regime. Not quite as eggregious as the 1950-1995 period that was used in some previous work by the authors, but still not good. I anticipate your response might be that you performed a removal of the NPI-explained part of the SWE time series and saw trend reduced only from -18.6% to -14.6%. This leads to my next point...

3) Natural cycles: I looked at streamflow data this past winter (when the email chatter within the UW on the snowpack issue was at its peak). Specifically, I looked at April-August runoff in three unmanaged watersheds in the west-side Cascades (Sauk, Skykomish, and Snoqualmie), from 1929-2005. I did a simple removal of the PDO-correlated part of the time series (like you did with 1 April snowpack and NPI), and the remaining downward trends in streamflow ranged from -4% to -8% for those three watersheds–substantially less than your remaining trend of -14.6%. Obviously we used different indeces, different water variables, and different time periods, so the results should not be exactly the same. But the discrepancy still seems large.

4) I did a quick check of the trends in Fig. 3, and the trend reported for panel (b), 1916-2003 looks like it should be more like -22% rather than -13%. With this correction, text (p. 2080, top) should read "...and slightly LARGER trend (22%)." Also, the next sentence should say trends since 1950 in the fixed-precip run were SMALLER rather than larger (this is just an error in the text–the relevant numbers in the figure are OK for trends since 1950). Of course this begs the question, how could trends since 1950 get smaller in the fixed-precip run, when precip since 1950 actually increased (Fig. 9a)?

5) My immediate reaction to the statement that the median snowpack elevation is around 1000 m (3281 ft) was "That can't be right!" My first guess would have been



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something more like 4000 ft or higher. I know from driving to Snoqualmie Pass in late winter/early spring that no significant snow is encountered until around Exit 47 (Denny Creek/Asahel Curtis), which is around 1600 ft. or 500 m. Using your Fig. 12a, the aerial coverage of 500-1000 m is about the same as from 1000 m up. Therefore, in order for the total snowpack to be the same below 1000 m as above it, the average SWE would have to be the same below 1000 m as above it. However, this is clearly not the case, as your Fig. 4b shows. I attempted to reproduce the calculation of the median snowpack elevation in the following way: I hand-converted your cumulative area vs. elevation graph (Fig. 12a) to area vs. elevation. Then, for each 50-m elevation band from 500 to 2050 m, I produced a total SWE for that elevation by multiplying the areal coverage for that elevation by SWE for that elevation. I estimated SWE vs. elev by visually fitting a line to Fig. 4b, which passes through the points (SWE=12, elev=500) and (SWE=134, elev=2000). I then made a cumulative distribution function for total SWE as a function of elevation, and obtained 1250 m (around 4100 ft.) for the 50%-SWE elevation. This seems much more reasonable to me than 1025 m (3363 ft.). Any reasonable linear fit to Fig. 4b will produce a similar result. Any thoughts on why your method produced 1025 m and mine produced 1250 m?

6) Related to point 5, I'm curious about two things: What area did you use as "the Cascades" in creating Fig. 12a? I constructed a similar graph, also using ˜4 km resolution data, and using an area approximately bounded by the Canadian border on the north, the Okanogan and Columbia Rivers on the east, the Columbia on the south, and Interstate-5 on the west. My graph was similar to yours, but I obtained a median elevation for areal coverage of 1025 m (considering only points above 500 m elevation), whereas yours gives a median elevation of 960 m (also considering only points $>$ 500 m). Perhaps it is explained by using different areas for "the Cascades". My second curiosity is that I wonder how the area vs. elevation distrubution might change if significantly higher resolution elevation data were used, such as 1 km or less.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 4, 2073, 2007.