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Interactive comment on "Assessment of the underestimation of snowfall accumulation by tipping bucket gauges used operationally by the Spanish national weather service" *by* S. T. Buisan et al.

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- Does the paper address relevant scientific questions within the scope of AMT? Yes
- Does the paper present novel concepts, ideas, tools, or data? Yes
- Are substantial conclusions reached? Mostly
- Are the scientific methods and assumptions valid and clearly outlined? Yes
- Are the results sufficient to support the interpretations and conclusions? Yes

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Discussion paper

- Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)? Yes

- Do the authors give proper credit to related work and clearly indicate their own new/original contribution? Yes, but discussion need some more citation

- Does the title clearly reflect the contents of the paper? Somewhat

- Does the abstract provide a concise and complete summary? Mostly

- Is the overall presentation well structured and clear? Mostly

- Is the language fluent and precise? Yes

- Are mathematical formulae, symbols, abbreviations, and units correctly defined and used? Yes

- Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated? Not really

- Are the number and quality of references appropriate? Yes

- Is the amount and quality of supplementary material appropriate? N/A

General Comments

Overall this is a well written paper that adds some new insight into undercatch of the Thies tipping bucket gauge. My big comments is that there could be some more discussion. The Discussion and Conclusions sections are combined and it could be useful to separate the two. There are limited citations in the Discussion, yet adequate in the Introduction. The authors state on line 10-11 of page 3 “[t]hese results are used to identify areas within Spain where errors affecting snowfall accumulation are most significant.” This is a very good application of the results to yield new important results. Revisit the literature on spatial precipitation patterns across Spain, etc., in the Discussion, i.e., how these results could change those previous studies.

Something that could be considered is the calibration and evaluation of the equations. More than 200 samples were used; is it possible to use a split sample approach to calibrate and evaluate the equations?

I have some thoughts about the project design, yet these are future consideration and do not affect how I read this paper. Repetition is good; it would be useful, at least as a backup to have a second and third Thies tiping bucket. Considering stating why there is only one Thies tiping bucket. Add a Hellman gauge as old Spanish observations were made with this configuration (p2, line 33). Does this include the Hellman shield? Where the Hellman gauges run concurrently with the Thies tipping bucket? The Thies tipping bucket gauges are heated (p3, line 28), and the evapo-sublimation problems (see Goodison et al., 1998) should be discussed. The "[w]ind was measured at a standard height of 10 m ..." which is a AEMET standard (p4, line 2). However, an addition of a gauge height wind measurement could be useful.<P> I have numerous comments to clarify the text, tables and figures. In general the paper is well written, and as such I can make these detailed comments to ask for further clarification. The Tables need some work to make them more understandable. The Table and Figure captions are too brief and need to be expanded to provide more insight. The Figures need some modification to make them easier to read and in some cases more intuitive. I suggest the use of double mass curves in several instances, such as Figure 5a, as they would provide more insight into event by event differences.<P>

Specific Comments

page 1, lines 1-3: the title could be shortened to remove some of the little words. How about "Assessment of the snowfall accumulation underestimation by Spanish National Weather Service operational tipping bucket gauges" Perhaps the name of the gauge "Thies tipping bucket" could be added, as this is the first time I have seen this specific gauge being adjusted for undercatch.

page 1, lines 27-29: it is appropriate to give specifics such as catch ratios, but this

seems awkward. Consider rewriting

page 1, lines 29-31: this sentence is unclear

p2, lines 2-3: the first sentence is not clear in terms of what "it" refers to. Is "it" the measurement or the accumulation?

p2, line 9: "undercatch" from "wind-induced updrafts" is not quite correct. It is more than just updrafts.

p2, line 16: "a secondary reference for solid precipitation" implies that there is a primary reference.

p2, line 25: is there a specific "automatic gauge" in the centre of the DFAR?

p3, line 1: cite the map (see my comments on Figures 1 and 2 below)

p3, line 7 (and throughout): I don't like the term "transfer" function. Mathematically this implies altering the pattern of the data, such as a Fourier transform. If this is a SPICE term, then disregard. If not, consider another term such as "equation" rather than "transfer function."

p3, line 7: the estimation of "true snowfall amounts" is not actually the case here, as this work aims to derive an equation or set of equation to estimate the DFAR snowfall amount. Yang et al. (1993 Eastern Snow Conference) showed that true snowfall is often more than DFIR snowfall.

p3, lines 8-10: reword "[t]he wind speed during snowfall events is included in this analysis to help determine the potential impact of wind-induced undercatch on Spanish snowfall measurements," to be more specific, i.e., wind speed (and temperature) data were used ...

p 3, line 16: "sub-alpine environment" is below the treeline, i.e., among the tree. This is likely the case here, but stating that the area "consist[s] of a mixture of bare ground and only very low grasses," makes us think it is in the alpine. If the site is in an opening,

state as such. Please clarify.

p3, line 17: consider showing a wind rose to illustrate that “[t]he prevailing winds are from the northwest all year round,” since this affects wind speeds (lines 18-21) through upwind fetch lengths, etc.

p3, lines 23, 27, 28: web links may be useful for manufacturers?

p3, line 30: the “non real time” output is not explained well.

p4, line 8: “1 minute data” which data? all variables or just wind speed and temperature?

p4, lines 11, 30, 35, etc.: It would be informative to show where the AEMET operational gauges were in Figure 2.

p4, lines 26-27: provide a citation for “these gauges have been progressively replaced.” Consider adding a time period for this replacement.

p4, line 32-33: “snowfall events were defined as precipitation events that occurred when the average maximum temperature was below 0°C.” What is the basis for this assumption? Snow can fall at air temperatures warmer than 0°C (e.g., Fassnacht et al., 2013 IAHS 360, 65-70).

p5, lines 6-7: be sure to clarify that differences in snowfall accumulation”yield less precipitation at the other gauges (SA, UN, TPB) than at the DFAR.

p5, line 11: the line “which agree to within 90 - 100%” is unclear.

p5, line 13: “The deviations in accumulations are most likely related to the wind-induced undercatch” is a weak statement. Consider rewriting.

p5, line 17: change the word “traces” here, as this has a precipitation implication (P < precision). Also consider the occurrence of snow (see Fassnacht et al., 2001, Journal of Hydrology 253, 148-168, Figure 1).

p5, lines 17, 18, p8line18, etc.: don't use "above", "below" or "near" to refer to temperatures, especially not 0°C, as these words have altitudinal implications. use warmer than (above), colder than (below), or at approximately (near).

p5, lines 18-19: "the threshold temperature of 0 °C is suitable for classifying the precipitation as snow and not rain for the site." Be careful with such statements, as the discrimination of rain versus snow can be difficult (e.g., Harder and Pomeroy, 2014, doi: 10.1002/hyp.10214) as is further stated.

p5, line 26: I would delete the word "ratio"

p6, line 18-23: this paragraph is unclear. I don't quite understand what was done here to derive the 9.5%

p7, line 4: change from "From this moment on" to "Hereinafter"

p7, lines 14-16: any relation with elevation and the presence of a canopy? It seems to go with the valley vs. plateau discussion earlier

p7, line 23: state the time period "for all snowfall events"

p8, line 10: "where" should be "were"

p8, lines 11-13: reword "However this was not necessarily because the wind speed was lower in these mountainous areas during snowfall events, as the measurement stations are generally located in the bottom of the valleys where they are less affected by the wind." This sentence is unclear

p8, lines 15-16: the phrase "higher losses due to undercatch" doesn't seem correct here. Consider saying something like "more total undercatch"

Table 2 is difficult to read. What is on the row heading (DFAR?) and what is on the column heading (TPB)? Is the top table for 1 h and the bottom for 3 h accumulation periods? I suggest spelling out TPB in the figure caption to help the reader. DFAR is assumed as a derivative of DFIR, so doesn't need to be spelled out.

Table 3: the caption is not informative. Explain that each step adds a new variable to transfer functions, and that the last equation is the application to correct the data. Reformat the table. Other statistics would be useful, such as RMSE or the Nash-Sutcliffe coefficient of efficiency. Consider including the number of data points used in each equation or set of equations.

Figure 1 and 2: can these be combined? Perhaps just put the Formigal-Sarrios star on the map of Europe-North Africa. The different mountain ranges in Spain are not relevant to this paper, as shown. Since part of the objective of this paper (p3, line 6-7) is to "demonstrate the importance of accurate snowfall measurements within this network," considering showing were these operational gauges are in the various mountain systems of Spain (Figure 8-11). "Altitude" is height above the ground; I suggest using the term elevation in Figure 2 (see p4, line 13).

Figure 2: The star is not in the correct location. "Formigal-Sarrios" is about at the top of the "P" in Pyrenees on the map. It should be at latitude 42.57 and longitude -0.62.

Figure 3a and b: the wind speed is difficult to see in the plots. Consider putting this in a separate stacked graph, with at least twice the scale in the y-direction. Consider putting a different (heavier?) line type for 0°C. A set of double mass curves compared back to the DFAR may also be informative.

Figure 4: change the x-axis from (-2,0) and (0,2) to "-2 to 0" and "0 to +2" I can't tell sleet from snow. Consider a different colour scheme, such as red for rain and blue for snow with green to yellow in between.

Figure 5a: what are the units on the y-axis? Consider using two (1h & 3h) double mass curves (cumulative precip vs. cumulative precip) with DFAR on the x-axis.

Figure 6: change (-2,0) to "-2 to 0" etc. It is difficult to distinguish "-2 to 0" and "<-6." Consider a different color for "<-6"

Figure 7: define "melting factor" in the caption.

Figures 8 and 9: also show m/s to be scientific - km/h is to be operational (p7, lines 4-5) Figure 8, use a), b) and c)

Figure 8, 9 and 11: can you use different color schemes? For Figures 8 and 9, they are different units and these colors could be confusing (maybe use greens ad greys). Repeating these colors in Figure 11 make it further confusing. In Figure 11, I would use yellow, orange and red to indicate a scale of ok to poor (e.g., caution, warning, alert). In Figure 10, red, white and blue are used. As these are only three colors, they are not as repetitive, but the legend is in the wrong order and red is used for the coldest temperatures while blue is used for the warmest. This is counter-intuitive.

Figure 11: is it possible to add “error” or "uncertainty" as a secondary map?

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