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Hydrology and Earth System Sciences
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Discussions

Interactive comment on "Technical note: Precipitation phase partitioning at landscape-to-regional scales" *by* Elissa Lynn et al.

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Summary Lynn et al. in "Technical note: Precipitation phase partitioning at landscape-to-regional scales" unveil a new rain-snow partitioning algorithm, the North American Freezing Level Tracker (NAFLT), and assess trends in California (and western US-wide) snowfall percentages in Winter (Dec-Feb), Spring (Mar-Apr), and Cool Season (Oct-Apr) over the last ∼70 years. To build the NAFLT, the authors utilize the NCEP/NCAR reanalysis (2.5-degree resolution) along with the PRISM (4km) reanalysis products. The authors find a more notable decline in rain-snow partitioning in spring (-2/decade to -4%/decade) than winter (-1%/decade to -2%/decade).

Overall, I think the paper by Lynn et al. is well within the scope of the Journal of

Hydrology and Earth System Sciences and a valuable contribution to the scientific community. The figures and results are well-posed and, importantly, the findings have both scientific and societal impact as rain-snow partitioning in mountains (particularly a regular, "healthy" seasonal snowfall total) is a critical assumption in water supply management of western US states.

Most of my comments and revision suggestions are regarding the need to fine-tune the narrative of the manuscript and further discuss/evaluate methodological uncertainties. I would suggest that the editor assign minor revisions to this manuscript.

Review Comments and Suggested Revisions:

Page 1 Line 11 – Change to, "...into rain and snow, particularly snow as it maximizes available water in spring-to-summer."

Line 21 – You might want to cite Huss et al., 2017 here... Huss, M., Bookhagen, B., Huggel, C., Jacobsen, D., Bradley, R., Clague, J., Vuille, M., Buytaert, W., Cayan, D., Greenwood, G., Mark, B., Milner, A., Weingartner, R. and Winder, M. (2017), Toward mountains without permanent snow and ice. Earth's Future, 5: 418-435. doi:10.1002/2016EF000514

Line 23-24 – Change to, "...and, in particular, frozen (snow) components was a foundational assumption of climate stationarity in the development of water management infrastructure and practices..."

Line 35 – Change to, "...Some examples include an upslope shift in winter snow levels..."

Line 37 – What do you mean by "decreased snowpack water storage efficiency"? Does this have to do with cold content decreases and snow ripening occurring more frequently throughout the snow accumulation season? Please clarify.

Page 2 Line 13 – Might want to point to a study (or several) that discuss the dataset/metric inadequacies that water managers/decision makers face when using

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climate information. For example… Jagannathan, K., A.D. Jones, and I. Ray, 0: The making of a metric: Co-producing decision-relevant climate science. Bull. Amer. Meteor. Soc., 0, https://doi.org/10.1175/BAMS-D-19-0296.1

Line 19 – Change to, "…scales and, therefore, could be an informative diagnostic for both model development and water resource management in snow dependent regions…"

Line 31 – Change to, "…higher with decreasing latitude where median annual precipitation greatest in the Northern Sierra Nevada…"

Figure 1 caption – Change to, "Estimated historical (1950-1969) percentages of…" In my opinion, the dataset resolution part is TMI in the figure and should just be stated in the methods.

Page 3 Line 3 – Just to clarify, DWR uses the proprietary 800m PRISM product, but did not give you access for this analysis? It would be interesting to know how much of a different answer one would get for rain-snow partitioning if you were to use the 800m vs 4km (i.e., 5x coarsening) PRISM product (particularly in the Southern Cascades)? Similarly, performing a sensitivity analysis of another 5x coarsening (∼20km) of the 4km PRISM product could be informative for climate modelers too. Given that these are diagnostic estimates of rain-snow partitioning, could the authors use the Sierra Nevada Snow Reanalysis (SNSR) from Margulis' group at UCLA - https://margulis-group.github.io/data/ - to explore how different of answer one might get using the author's method vs other methods? This could also include (at least qualitatively) a comparison between more physics-based rain-snow partitioning estimates/trends in the literature versus NAFLT.

Line 20-25 – Might be helpful to cite Jennings et al., 2018 when discussing the "hydrometeor energy balance theory" of snowflakes persisting in above freezing temperatures. Jennings, K.S., Winchell, T.S., Livneh, B. et al. Spatial variation of the rain–snow temperature threshold across the Northern Hemisphere. Nat Commun 9, 1148 (2018).

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https://doi.org/10.1038/s41467-018-03629-7 As you expand NAFLT for use beyond the Sierra Nevada (i.e., a more maritime mountain), it might be important to build in (or at least assess the sensitivity of adding in) specific humidity/relative humidity into the rain-snow partitioning algorithm.

Page 4 Line 1-2, Figure 1 – It might be useful to also plot a median snow water year (e.g., 2007-2008)? Also, why not use 1982-1983 for the max snowpack year (DWR's max SWE year - http://cdec.water.ca.gov/snowapp/swcchart.action)?

Line 4-8 - This is beyond the scope of this current study (and seems to be discussed more in Hatchet et al., 2017 and in the "Primary Limitations" section of this article), but given that NCEP/NCAR reanalysis is fairly coarse (2.5-degree resolution) do the authors have a sense of the magnitude of uncertainty baked into rain-snow partitioning estimates in the NAFLT (i.e., confidence intervals)? For example, the freezing isotherm may be influenced by aggregation of sharp gradients in topography in NCEP/NCAR (i.e., resolution dependence) and the precipitation estimates may lack extreme precipitation events (i.e., statistical relationship assumptions in PRISM and/or coarse grid averaging in NCEP/NCAR) and/or may be lower bound estimates of orographic enhancement of storms. The use of the new ECMWF generated ERA5 reanalysis product (i.e., global, 1950-present, hourly/monthly, ~30km, up to ~137 vertical levels) might be a path forward to explore/address any uncertainties in NAFLT too (https://confluence.ecmwf.int/display/CKB/ERA5%3A+data+documentation). At the very least, I think a brief discussion in the manuscript on the potential sources (or even magnitudes and confidence intervals) of uncertainty within the NAFLT rain-snow estimates might be useful and informative to users.

Figure 2 – Is there any value in looking at trends in Oct-Nov too? I am curious if there is an asymmetric or symmetric response in rain-snow partitioning between the "shoulder" months of the Cool Season.

Line 21-30 – Is there any added value in evaluating sliding (rather than fixed) decadal

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trend analysis? Or, more specifically (may be a follow-up study), isolate trends based on certain climate variability indices? For example, the ENSO Longitude Index (ELI)... Patricola, C.M., O'Brien, J.P., Risser, M.D. et al. Maximizing ENSO as a source of western US hydroclimate predictability. Clim Dyn 54, 351–372 (2020). https://doi.org/10.1007/s00382-019-05004-8

Line 21-30 - Figure 3 – Do the authors want to discuss potential physical mechanisms regarding the much larger Spring declines in rain-snow partitioning on the leeside (i.e., -4%/decade) compared with windward (i.e., -1-2%\decade) of the Sierra Nevada, particularly in the northern-to-central HUC watersheds? Topography is mentioned but given that there is an asymmetric response between even abutting windward and leeward HUC watersheds (and this is more seen in the Spring rather than Winter), are there potential physical mechanisms that should be discussed? For example, are these changes due to less Spring storms overall or are there the same number of Spring storms, but they are warmer and thus more readily produce rain? Another difference could be that the leeward HUC regions mix trends in the Sierra Nevada with the White Mountains and mask storm-type changes in rain-snow partitioning (e.g., large-scale vs convective and/or inland AR penetration).

Line 28 – Change to, "...remain upslope of the 0 degree C elevation..."

Page 5 Line 5-6, Figure 4 – In addition to watershed area (i.e., proxy for volume of snowpack lost), it might be good to note or discuss other downstream impacts too (i.e., the acre-foot storage of reservoirs, importance of tributaries for surface water, endangered species habitat, etc.). For example, even smaller declines (at least from a water resource management perspective) above Lake Shasta might matter more than more marked declines in watersheds that do not have a reservoir downstream of them (or the reservoir storage capacity is much smaller).

Line 30-31 – Might want to cite a healthy number of future climate modeling studies of the western US here.

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Page 6 Line 1-2 – Although a bit tangential to the work in this study, it could be useful to cite some other water supply strategies that can help to offset decreases in mountain snowpack (e.g., recycled water, stormwater catchment, etc.). Some of these supply-side strategies have, historically, been undervalued, but now that co-benefits are being assessed the $/acre-foot start to make more sense and could help to offset the projected low-to-no snow future California might face. . .

"Economic evaluation of stormwater capture and its multiple benefits in California" - https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0230549

"...current economic analyses of stormwater capture do not adequately examine differences in stormwater project types and do not evaluate co-benefits provided by the projects. As a result, urban stormwater capture is undervalued as a water supply option. To advance economic analyses of stormwater capture, we determined the levelized cost of water in U.S. dollar per acre-foot of water supply (AF; 1 AF = 1233.5 m3) for 50 proposed stormwater capture projects in California, characterizing the projects by water source, process, and water supply yield."

"The cost of alternative urban water supply and efficiency options in California." - https://iopscience.iop.org/article/10.1088/2515-7620/ab22ca

"...this analysis evaluates the costs of four groups of alternatives for urban supply and demand based on data and analysis in the California context: stormwater capture; water recycling and reuse; brackish and seawater desalination; and a range of water conservation and efficiency measures. We also describe some important co-benefits or avoided costs, such as reducing water withdrawals from surface water bodies or polluted runoff in coastal waterways...."

Line 9-10 – I am still on the fence about the argument that "model-based estimates > gridded statistical estimates" for precipitation/snowfall in mountains. There is a lot of nuance that needs to be discussed with this "movement" (which seems primarily "all-in" on WRF). For example, I think some of the assumptions/limitations of micro-

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physics/macrophysics schemes and boundary layer schemes in climate models need to be discussed (particularly in the context of mountains). I know this is an on-going debate (and my $0.02 is one of many), but I would ease the definitive statement regarding "skill" made here.

Line 29 – Change to, "...is that NAFLT can be periodically updated, as datasets become available, with higher resolution gridded data products (citations) and expanded in scope to evaluate global rain-snow partitioning."

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