Author responses to referee C269 comments on Manuscript: ESSD-2013-24, entitled "Soil, snow, weather, and sub-surface storage data from a mountain catchment in the rain–snow transition zone" – Earth System Science Data (Discussions)

- **Reviewer comments are in bold font and author responses are in normal font.**
- **Page and line number references are to the original manuscript unless otherwise noted.**
- **Quotes from the text are italicized and proposed revisions are noted by underline.**

RESPONSES TO REFEREE C269 COMMENTS TO AUTHOR:

Specific Comments

1. **p.812 line 5 – after "rain-on-snow" no abbreviation (ROS);**

   We didn't think it was appropriate to use abbreviations in the abstract. We will include it in the revised manuscript at the editors request.

2. **p.812 line 16 - using a single water year is insufficient for most tasks related to the hydrological modeling.**

   We agree with the referee in that many hydrologic modeling tasks require multiple years of data. The main point of this statement is that the wealth of both above and below ground data (including many subsurface soil property measurements) provides the unique opportunity to parameterize many different types of hydrologic models that require such data. Next, we feel that the sufficiency of the duration of the presented data is dependent on the specific problem being addressed. The text states, "*…a wide range of modeling and descriptive studies*". Here we refer to the modeling of hydrologic processes, and not larger scale stream flow modeling. We therefore propose to leave in statements about the usefulness of this dataset to modeling and descriptive studies on page 812, lines 16-19, but modified to be more specific as follows: "*Though <u>the weather, snow, and hydrologic response data only covers one</u> water year, the presentation of <u>the additional subsurface data (soil depth, texture, moisture, and temperature)</u> makes it one of the most detailed and complete hydro-climatic datasets from the climatically sensitive rainsnow transition zone. <u>The data presented are appropriate</u> for a wide range of modeling <u>(energy balance snow modeling, soil capacitance parametric modeling, etc.)</u> and descriptive studies.*"

   Finally, we note that there is a much longer duration dataset for this and other locations within the Dry Creek Experimental Watershed available at: earth.boisestate.edu/drycreek/data/ and through the CUAHSI Hydrologic Information

System. The data presented in this article for the 2011 water year differs from that data by having weather and streamflow data gap filled to the best of our ability. We also include snow survey data and data from the 5 additional ultrasonic snow depth sensors. We propose to include the following statement under the "Data availability" section on page 820, line 13: "*Additional weather and hydrologic response data for the Treeline Catchment and other catchments within the Dry Creek Experimental Watershed are available at earth.boisestate.edu/drycreek/data/ and through the CUAHSI Hydrologic Information System.*"

3. **p.814 lines 16-18 - indicated the possibility of using a database for physically-based hydrological modeling. Basic principles are correct, but in the relevant studies the duration of observations should be at least 4-5 years (not only single year);**

   Please refer to response to Specific Comment 2 above.

4. **p.814 line 20 – indicated the possibility of using database for empirical hydrological models. Duration of observation is too short for build robust model. We can also test and validate our model, so 4-5 years required;**

   The statement on line 20 of page 814, "*Detailed topographic data combined with soil moisture measurements can be used to evaluate topographic indices common to many empirical streamflow modeling approaches (O'Loughlin, 1981, 1986; Beven and Kirkby, 1979).*" was meant to suggests that this dataset may be useful for evaluating commonly used topographic indices in empirical models. We were not suggesting the use of this dataset to calibrate and test empirical models themselves. We thank the referee for pointing out the lack of clarity in this sentence. We propose the following amendment to the sentence in question: "*Detailed topographic data combined with soil moisture measurements can be used to evaluate the underlying topographic indices commonly used in many empirical streamflow models (O'Loughlin, 1981, 1986; Beven and Kirkby, 1979).*"

5. **p.814 line 23 – incorrect indication on the possibility for hydrological classification. Techniques that are referenced by the authors does not work well at different scales and can be applied mainly to the set of medium-sized watersheds (not for classification within Treeline basin);**

   We agree with the referee. The sentence and reference, "Traditional watershed hydrology methods, such as annual water balances, can be used to make generalizations on geographic regions and watershed classifications (Wagener et al., 2007)." from lines 23-25 on page 814 will be removed from the manuscript.

6. **p.815 line 1 – basin area can be represented in square kilometers;**

We thank the referee for their suggestion and will include km^2 in the units of the basin area.

7. **p.815 line 1 – no space between 21 and ° (degree sign);**

   We will omit the space as suggested.

8. **p.816 lines 4-16 – (Incoming radiation) in the article included algorithm for filling gaps (amazing 48%), but in dataset file FOUR_COMPONENT_RAD.txt gaps are;**

   We thank the referee for pointing out the lack of clarity about the methods used to obtain a gap filled incoming longwave radiation time series. We propose changing the name of this section from "*Incoming Radiation*" to "*Radiation*" and inserting the following text into section of the manuscript: "Serially complete incoming shortwave and longwave radiation time series are presented in WEATHER_DATA.txt. Incoming and outgoing shortwave and longwave radiation data as measured at the four component radiometer is presented in FOUR_COMPONENT_RAD.txt and are not gap filled."

9. **p.816 lines 17-30 – (Air temperature and humidity) no brief explanation of using Marks et al. (1999) formula and its advantages over standard Magnus formula;**

   Many methods for deriving dew point temperature from temperature and relative humidity are optimized for standard temperature and pressure conditions (generally 12 – 15C). While the Magnus formula has many suggested sets of coefficients, we are unfamiliar with the error in results around freezing temperatures. Marks et al. (1999) presented a suite of tools used to determine saturation vapor pressure, and dew point temperatures based on fitting equations to the tables in the CRC Handbook of Chemistry and Physics (Lide, 1992). These equations are optimized such that the solution is most accurate around 0° C. This provides very accurate values in the temperature range (-2.5° C to +2.5° C) critical to determining precipitation phase, with reduced accuracy at warmer temperatures. The approach is within 0.001 at 0° C, falls to about .01 at +/-8˚ C. We have included citations to Marks et al. (1999) and an additional paper (Reba et al., 2011) within the manuscript such that the above information is not needed in the text of the manuscript. The citations are as follows:

Marks, D., J. Domingo and J. Frew, 1999. Software tools for hydro‐climatic modeling and analysis: Image Processing Workbench, ARS ‐ USGS Version 2. ARS Technical Bulletin NWRC-99-1, Northwest Watershed Research Center, USDA Agricultural Research Service, Boise, ID, Electronic Document: http://199.133.140.121/nwrc/ipw/intro.html.

Lide, D.R., editor, 1992, Handbook of Chemistry and Physics, 72nd addition, 472pp, ISBN 0-8493-0472-5.

Alduchov, Oleg A., and Robert E. Eskridge. "Improved Magnus form approximation of saturation vapor pressure." Journal of Applied Meteorology 35.4 (1996): 601-609.

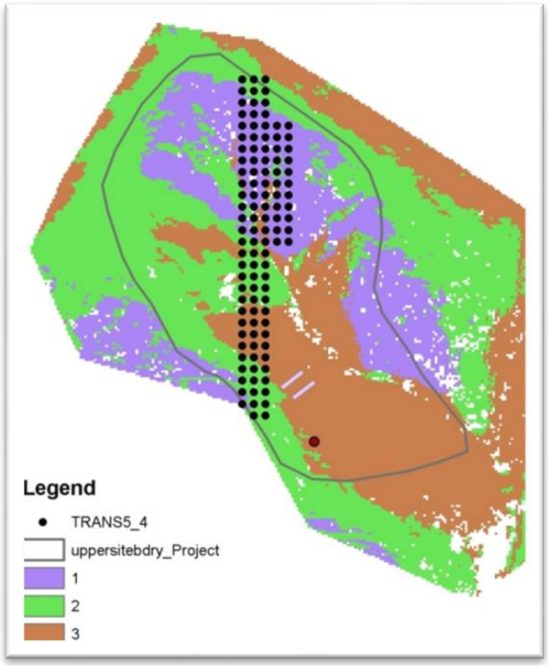
10. **p.818 lines 11-17 - lack of data of snow cover. Complete set of measurements is available only from January 21, thereby was missing a very important period for the hydrological system - snow cover formation period;**

    We agree with the referee that snow survey data during the formation period would be ideal. Snow cover data during the snowpack formation is available in the form of ultrasonic snow depths. One of the sensors has continuous gap-filled data for the entire water year (available in WEATHER_DATA.txt), and 5 others have data (not gap filled) starting on January 19th (SNOW_DEPTH_USD.txt). We did not attempt to gap fill snow survey data or snow depth data from the other 5 sensors because this falls under our hydrologic response, or "model validation" data. This paper focuses on providing a serially complete weather data set, or "forcing" data, and provides snow data "as measured". We have modeled snow conditions across this basin for the entire 2011 water year, but this "modeled data" is beyond the scope of this data paper. We propose to include the following statements in the "Abstract" on page 812, line 11: "*This data is often viewed as "forcing data", and is therefore gap filled and serially complete.*" Then on line 16 on the same page, we propose to include "*Snow and hydrologic response data are meant to provide data on the catchment hydrologic response to the weather data. This data is mostly presented "as measured" although snow depths from one sensor and streamflow at the catchment outlet have been gap filled and are serially complete.*" We will also modify the "Introduction" on page 814, lines 16-18 as follows: "*Model developers can use distributed soil and topographic data to obtain state variables, serially complete and gap filled weather data to drive, and snow, soil moisture, and streamflow data to evaluate model performance*."

11. **p.819 lines 4-9 – snow survey data represents a small area of the Treeline watershed (only a narrow band across the valley). Why were not snow surveys carried out over the entire basin (equally over the basin);**

    We thank the referee for pointing out a statement in our manuscript that requires more explanation, and we agree that a repeated, gridded snow survey of the entire basin would have been a great data set.

    Lines 20-23 on page 818 state, "*Surveys were designed to capture snow depth and snow water equivalent differences within the catchment (Winstral and Marks, 2013) based on LiDAR derived depth similarity classes (Shallcross, 2011).*" We propose adding the following after this sentence: "*This knowledge of typical snow distribution and variance at the Treeline catchment allowed us to characterize the snow storage by sampling a small portion of the catchment area*." Shallcross (2011) divided the larger Dry Creek Experimental Watershed, which contains the Treeline Experimental Catchment, into groups with similar snow depth and variance. There were 10 original depth similarity classes within the Treeline Catchment. We combined these 10 classes into 3 new classes because many of them had very similar average depths, but different variances. When combining classes, the new class received an area weighted depth but retained the maximum variance of the classes that were combined. Based on the resulting 3 depth similarity classes, we designed a practical snow survey that sampled all classes according to the variance of each class (higher variability classes were sampled more). The following figure details the depth classes and the snow measurement locations. The 3 colors map out the depth similarity classes within the basin.



Also, we did attempt a weekly, gridded survey for the 2012 water year and concluded that repeating a survey of this nature on a weekly basis entails substantially more time and effort, even for a basin of this size.

12. p.819 lines 11-21 (Stream discharge) - data are not available until December 16, and the relation with neighboring watershed to fill gaps is not justified in the clear way;

The stream in the Treeline experimental catchment is ephemeral as is stated on line 13 page 815, and as the referee points out in specific comments. There are also much larger basins in this semi-arid environment that are ephemeral. Streamflow data is measured from December 16, 2010 and continues to the cessation of flow. Missing streamflow data between streamflow initiation and December 16, 2010 is estimated because of equipment malfunction, as is stated on lines 13-18 on page 819. This is also stated in the README_DATA.txt file under the section that describes the STREAM_DISCHARGE.txt file. Ideally this data would have been measured. We had installed two measurement systems prior to the onset of streamflow in the early winter of 2010. Both of these systems failed. This highlights the challenges associated with collecting long-term and serially complete field data sets. Replacement sensors were installed and functional on December 16th. We infer that we did not record early streamflow events from other, nearby stream gauging stations.

Treeline streamflow is strongly related to streamflow from other gages within the Dry Creek Experimental Watershed. Though the Treeline gage malfunctioned between October 1, 2010 to December 16, 2010, we were able to gap fill the missing period using a least squares linear regression to two other nearby gages in the Dry Creek Experimental Watershed (Con2Main (C2M on map) and Lower Gauge (LG on map)) (http://earth.boisestate.edu/ drycreek/data/). Streamflow for these gages and the Treeline gage data between October 1, 2010 and March 17, 2011 were used to develop the regression (R^2=0.9246). The resulting modeled Treeline streamflow was adjusted to better fit 3 manual measurement points on December 13th, 14th, and 15th, 2010, and to avoid an offset issue at the beginning of the automated measurements on December 16th. We are confident that the resulting estimate for Treeline streamflow during the fall of 2010 – the early part of the 2011 water year – is the best possible, and is generally reliable. We propose to include this information (on gap filling methods and regression fit) in the README_DATA.txt file.

13. **p.830 fig.1 – no contours labels, altitude scale is inverted (usually the lower areas are shown in green, and the highest – in dark brown). Finally, I (and somebody else, I think) would like to see the approximate location of the rain-snow transition zone.**

    We thank the referee for their suggestion. We will include contour labels in figure 1. We will also include an estimated rain snow transition zone on the inset map of Dry Creek Experimental Watershed. The entire Treeline Catchment is within the rain-snow transition zone. The elevation scale having brown in the lower elevations and green in the upper elevations is applicable to this area since the low elevations are much dryer (and browner in the summer) than the higher elevations that get enough precipitation to support conifer trees. We propose to leave the color scale as presented.

Additional Comments

1. **The dataset will be the more useful and complete after adding additional information of ROS events, like a current time, duration, intensity and coverage.**

    The following table includes the time, duration, and intensity of the rain on snow events. The spatial coverage of the precipitation events are assumed to be the entire catchment given the size of the catchment. These are obtained from hourly precipitation time series. We can either include this table in the manuscript, or leave it as part of the discussion at the digression of the editor.

Rain on Snow Time Period	Precipitation (mm)	Mean Intensity (mm/hr)	Maximum Intensity (mm/hr)
Dec. 14 6:00 to 10:00	13	2.6	5.3
Jan. 16 9:00 to Jan. 17 1:00	34	2.0	4.6
Mar. 13 17:00 to Mar. 14 7:00	8	0.5	1.7
Mar. 15 11:00 to Mar. 16 1:00	23	1.6	4.1
Apr. 2 8:00 to 10:00	6	2.0	3.0
Apr. 5 0:00 to 11:00	12	1.0	3.3
Apr. 9 4:00 to 10:00	2	0.3	0.6

2. **Snow surveys were made by different instruments. Will obtained measurements have the same (equal) values?**

    Snow depths recorded with traditional depth probes and with the Magnaprobe (SnowHydro, http://www.snowhydro.com) produce snow depth measurements within 1 cm accuracy when used by trained personnel. Accurate density measurements using any method, however, are extremely difficult to obtain in this rain snow transition zone due to a combination of shallow snow, constant melt and refreezing conditions, and shrubs. We expect snow density measurements taken with a density cutter to be more accurate than those taken with a federal tube. There are no reliable studies that compare measurements between snow density measurement methods. We expect that with skilled personnel and ideal conditions, we can expect 5% accuracy at best.

3. **After reading I got the impression of lack of a clear line of research, lack of clear purpose of dataset creation, and chaotic, fragmentary and somewhere negligence nature of the study. Because of this, only a small part of the huge amount of data collected can be used for hydrological studies.**

   We thank the referee for pointing out the need for additional clarification of the purpose of this dataset. We propose adding the following text to the introduction that clarifies the purpose of the dataset: "The purpose of this data set is to provide all of the available soils, vegetation, weather, and hydrologic response data from a study site within the rain-snow transition zone." The data set enables us to better understand the multitude of different snow and subsurface processes that occur in the rain-snow transition zone, specifically during snowmelt and rain-on-snow events. The intermittent behavior of the catchment stream, along with soil moisture dynamics, also provides the opportunity to study streamflow initiation and cessation in these small catchments. We also note that the data provided will support many different types of models, including full energy balance, temperature index, and soil capacitance based parametric models. Please also refer to the response to specific comment 10 regarding additional proposed text that would clarify the purpose of the dataset.

4. **Based on the ESSD evaluation criteria, authors' dataset satisfies uniqueness and usefulness criteria, but not the completeness. To fully comply with the requirements of ESSD, authors must provide information about snow cover conditions from the time of its formation, and stream discharge measurements for the whole year.**

   We thank the referee for their careful evaluation of the data set and manuscript. We feel that we have satisfied ESSD requirements by providing information about the snow cover conditions and stream discharge.

   The snow pack was continuously monitored during the 2011 water year at the Treeline Catchment. Snow cover data during the snowpack formation is available from an ultrasonic snow depth sensor, which has continuous gap-filled data for the entire water year (available in WEATHER_DATA.txt). Five other ultrasonic snow depth sensors have data (not gap filled) starting on January 19 (SNOW_DEPTH_USD.txt). In addition, data from 10 weekly snow surveys is available in the SNOW_DENSITY.txt file and multiple files in the GIS_DATA directory.

   Stream discharge measurements are not available for the entire year because the stream in the Treeline catchment is ephemeral. Therefore, a "zero" or "no-flow" measurement is common. We provide a complete, gap filled stream discharge record available in the STREAM_DISCHARGE.txt file.