This paper evaluates the simulation results on the liquid-vapor-air flow mechanisms between snowpack and soil by coupling a snow module and a soil module. The authors made great efforts to couple the models and made a detail analysis of their results. However, three major concerns are rising from the unclear purpose of this article, the weakness of the coupling method, and the unconfident results due to missing snow observation.

We thank the reviewer very much for the time processing our manuscript. We made our point-by-point response as below.

Major concerns:

1. What do the authors want to find by considering various complexities of mass and energy transfer physics? Isn't a more comprehensive parameterization scheme, without any simplification, is better for a snow-soil model? Are there any physically-based conflicts between different sub-models? Or are any sub-models a fault, so the authors had to find it out by this coupling?

Response: From the model process understanding perspective, we agree that a more comprehensive parameterization scheme is a better choice. From the application perspective, most of current land surface models or snow-soil models usually adopt a simplification of soil mass and energy transfer scheme (basic water and heat coupled, with no vapor flow and airflow). It has been reported that the consideration of the tightly coupled water and heat transfer scheme and vapor flow and airflow is important for the realistic interpretation of the soil hydrothermal dynamics in cold regions. However, the relative role of water and heat transfer scheme, vapor flow, airflow in portraying the soil hydrothermal regimes with snowpack is rarely presented. This work is trying to figure out whether the difference in soil physical processes affects the simulations and what is the role of individual processes in the soil hydrothermal state simulations with the snowpack. It helps to find under what conditions the specific processes are important and cannot be overlooked. Thus it can provide the guidance on the model development about how complex the soil physical processes should be taken into account in cold regions.

We added some relevant text in the Introduction part. See Line 76-91.

2. The key of this paper is the heat-water interaction between UEB and STEMMUS-FT. However, the UEB model may not be a good choice since it considers the snowpack as a 1-layers object, ignoring the significant temperature change on different snow profiles. The authors need to clarify: 1) whether the UEB model gives the temperature of snowpack bottom since it is the most critical boundary condition for solving soil heat transfer. 2) whether the water flows from snow would bring heat to soil. If YES, how did you considered the water flow temperature? 3)whether the solar radiation penetration was considered in your method since the snowpack would be very shallow in the Tibetan Plateau.

Response: Thanks a lot for the critical comments. Using the developed model, this manuscript is currently focus on investigating the effect of snowpack on soil hydrothermal dynamics. UEB model is selected for its simple yet physically based snowpack energy balance parameterization, which can well simulate the snowpack dynamics. We agree that the temperature profile within the snowpack is not captured well by the single layer snowpack model UEB (UEB only explicitly simulates the snow surface temperature and the average snowpack temperature). The temperature of snowpack bottom is not given by the UEB model. Here we used the in situ surface temperature measurements as the boundary condition for solving the soil heat transfer, by which the thermal effect of snowpack was implicitly considered. For our next step, we are willing to implement the energy balance as the boundary condition for the soil heat transfer. As long as the snowpack is presented, the soil surface energy balance was recalculated to consider the effect of the snowpack on the energy budgets. It includes explicitly the convective heat due to the melt snow water, conductive heat, and the solar radiation attenuation.

In addition, the radiation components were also affected as the presence of the snowpack. In UEB model, when the snowpack is shallow, the albedo is weighted between the snow albedo and bare ground albedo $A_{v/ir} = r\alpha_{g,v/ir} + (1-r)\alpha_{v/ir}$. The weighting factor $r = \left(1-\frac{z}{h}\right)e^{-z/2h}$, in which the solar radiation penetration in the snow is exponentially attenuated as expressed by the exponential term. The incoming radiation is then altered, and the other energy budget components will be affected accordingly.

We added the relevant clarification in the Section 2.1 and 2.3.

3. The topic is the coupling between parameterizations of snow and soil. However, there is no direct snow observation such as snow depth. The ALBEDO or other variables could only provide indirect evidence. So, it is not confident for me to agree with the authors on the benefits of STEMMUS-UEB. I suggest the authors using a more comprehensive dataset to evaluate your model. Some supersites for the cold region, even in Tibetan Plateau, such as the super snow and frozen-ground observations network in Qilian mountain (Che et al.,2019), could provide enough dataset for your evaluation and similar job (Li et al., 2019).

Che, T., Li, X., Liu, S., Li, H., Xu, Z., Tan, J., Zhang, Y., Ren, Z., Xiao, L., Deng, J., Jin, R., Ma, M., Wang, J., and Yang, X.: Integrated hydrometeorological, snow and frozen-ground observations in the alpine region of the Heihe River Basin, China, Earth Syst. Sci. Data, 11, 1483–1499, https://doi.org/10.5194/essd-11-1483-2019, 2019.

Li, H., Li, X., Yang, D., Wang, J.,Gao, B., Pan, X., et al. (2019).Tracing snowmelt paths in an integrated hydrological model for understanding seasonal snowmelt contribution at basin scale. Journal of Geophysical Research: Atmospheres,124.

Response: We thank the reviewer very much for the comments.

Albedo has been demonstrated significantly correlated to the snow cover. This is also true for the super snow station Yakou in Qilian mountain (Figure R1). Together with the auxiliary meteorological data, the dynamics of surface albedo can be used to properly infer the presence of snowpack and the period during which it affects land surface processes (please see Table R1, Figure R1 and Figure R2, using Yakou super snow station data as an example). Given that results, we can take the albedo as the valid indicator of the presence and influencing period of the snowpack. As such, we conducted the analysis of the effect of snowpack on the soil hydrothermal regimes.

We used the dataset suggested by the reviewer and ran a simulation using the developed model. The results were presented in the Appendix B. The simulation results demonstrated the validity of the STEMMUS-UEB model. The difference between models with and without the snow module is clearly presented in Figure B1-B5.

Minor comments:

4. Line 21-22. It may not be suitable to use "the effect of snowpack on soil moisture and heat transfer" since there is the only comparison among different parametrization schemes, but not a reliable analysis of this effect based on the examined model and its proven results.

Response: Following the relation between surface albedo and snowpack, we can confirm the presence of the snowpack and its lasting time with the meteorological data. It is also validated from the Yakou super snow station in Qilian mountain. We added the figures indicating the relationship between the surface albedo and snowpack. Table R1 and Figure R1-R2 show that the surface albedo can be a reliable indicator for the presence of snowpack.

With and without the snow module, the precipitation and following processes are treated differently. Only with the snow module, the precipitation can be partitioned into the rainfall and snowfall components. The snow accumulation and melt processes are explicitly considered. The water reaching the soil surface is thus altered both in the amount and time. Given the different incoming water flux, we investigate how the models with different soil physical processes respond and further connect it to the observed state variables.

5. Line 69-70. Many models such as SHAW, CLM, and CROCUS all consider the underlying soil physical processes. In addition, what is the meaning of air balance in Table 1? If the air balance has notable influences on the modeling, please explain it with some references.

Response: We agree that many models consider both the snowpack and the underlying soil physical processes. Nevertheless, most of them do not implement the multi-parameterization of the soil physical processes and rarely consider the role of airflow.

Air balance represents the conservation of air fluxes in soil. Dry air transfer in the soil is driven by the dry air concentration/density gradient and the air pressure gradient. It includes four parts: 1) the diffusive flux (Fick's law, $D_e \frac{\partial \rho_{da}}{\partial z}$), driven by dry air density gradient; 2) the advective flux (Darcy's law, $\rho_{da} \frac{S_a K_g}{\mu_a} \frac{\partial P_g}{\partial z}$), driven by the air pressure gradient; 3) the dispersive flux (Fick's law, $\left(\theta_a D_{Vg}\right) \frac{\partial \rho_{da}}{\partial z}$); and 4) the advective flux due to the dissolved air (Henry's law, $H_c \rho_{da} \frac{q_L}{\rho_L}$).

The effects of airflow on soil mass and energy transfer are two-fold. First, it directly results in the additional water and vapor fluxes and corresponding convective heat flow. Second, the presence of airflow in soil pores alters the water vapor status (density, pressure) thus the vapor transfer processes, which have been demonstrated important in soil water and heat transfer.

Several papers have reported the influence of airflow on the soil water and heat transfer. It can significantly retard the infiltration (Touma and Vauclin, 1986; Prunty and Bell, 2007), enhance the evaporation after precipitation (Zeng et al., 2011a, b; Zeng and Su, 2013), and cause the convective heat transfer and thus the temperature difference between the upper and the lower part of a permafrost talus slope (Wicky and Hauck, 2017).

We added the relevant description in the Introduction part of the updated manuscript. See Line 76-91.

6. Section 2.1 is just like an introduction of the SEMMUS model, but the readers would be firstly interested in your methods in this paper. I suggest presenting the coupling method first and then detail the two models separately.

Response: We adjusted this section and presented the coupling method first and then detail the two models as further explanation. A paragraph summarizing this section was also presented.

Changes in the manuscript are:

"This section first presents the coupling procedure of STEMMUS-FT and UEB model, followed by the detailed description of the two models and their successful applications. Then the used model configurations and two tested experimental sites in the Tibetan Plateau were elaborated. Maqu case is for investigating the effect of snowpack on the underlying soil hydrothermal regimes. Yakou case is for demonstrating the validity of the developed STEMMUS-UEB model in reproducing the snowpack dynamics (results were presented in Appendix B)."

7. Line 94. What is the job this reference cited?

Response: Clark et al. (2015) advocated that it is necessary to develop the integrated model, under the same model structure, with various parameterization of land surface processes. In such way, it avoids the misinterpretation of the model-comparison results and focus on the comparison of the relevant processes.

We deleted this reference here.

8. Line 100. It may not be the only linkage because the water flow would transfer heat and mass simultaneously.

Response: Yes. Many thanks. We agree that water flow can transfer the mass and heat flow. The convective heat flux transferred by the water flow is usually less than that by the vapor flow.

We rephrased the sentence as "the primary linkage between soil water and heat flow". Line166.

9. Line 117. Why first order? A little weird.

Response: We use the first order to stress that the UEB model can capture the primary characteristics of snowpack well. We deleted the "first order".

10. Line 127. Could you please specify the means of the one-way?

Response: Currently, as we more focus on investigating the influence of snowpack on subsoil hydrothermal regimes, the feedback effect of soil hydrothermal dynamics on the snow dynamics was relaxed. The surface temperature measurements were considered as the topsoil energy balance boundary conditions. In such way, the topsoil boundary condition is reliable, and the interactive soil-snow effect is implicitly considered.

From the perspective of water fluxes, the meltwater from snowpack was added to the subsurface soil, in addition to the rainfall, as the topsoil boundary condition for solving soil water transfer.

We focus on investigating the effect of the snowpack on the subsurface soil water and vapor transfer. And, thanks for your comments, we found the 'one-way' somewhat confusing and deleted it. In addition, we added some explanation text in the updated Section 2.1 accordingly.

11. Line 132. Did the UEB model simulates the meltwater temperature and includes it in the heat flux output? I am also interested in the temperature of the snowpack bottom that the UEB model could give or not. As the authors suggest, the UEB model assumed the snowpack as a single layer, so the snowpack temperature is very different from the underlying boundary temperature of the snowpack, which is the most crucial heat boundary for solving the heat transfer in the soil matrix. Also, solar radiation should be considered since it could penetrate about ~10 cm into the snow if there are shallow snowpacks.

Response: We agree with the reviewer that the effect of snowpack on energy budgets are important. Currently, UEB can provide the snow heat content, which is for estimating the snowpack average temperature. The convective heat flux due to the meltwater can be simulated by UEB as the heat flux output. UEB cannot provide the temperature of the snowpack bottom for the heat boundary condition solving the soil heat transfer. The current solution is to take the *in situ* surface temperature as the topsoil heat boundary. The aim of this work is first to identify the presence of snowpack and then investigate the effect of snowpack on the subsurface soil water and vapor transfer processes.

In the following updates, your suggestions were to be implemented. The energy balance conservation will be set as the topsoil heat boundary condition. The snowpack meltwater heat flux, attenuation of solar radiation by the shallow snowpack and albedo changes can be explicitly taken into account in solving soil heat transfer.

Some text was added in the section 2.1 and 2.3.

12. Line 148-153. I am confused with the reason to set these three cases. Would you please specify the purpose, which is to find a simple but effective enough coupling method? Is it not the most reliable method to include all physical processes?

Response: With these three cases, we can readily know the capacity of each soil physical parameterization. For instance, the effect of snowpack on underlying soil water and vapor transfer can not be realistically produced using the basic water and heat coupled model.

We can investigate the underlying physics and explain what happens after snowfall. The more complete the physical processes considered the model is more explainable. While under which condition the specific process is important and to what extent its importance is should be investigated. Here we would like to investigate the role of different soil physical processes in affecting the results. It can help to understand the underlying physics and to guide the future development of models.

13. Section 2.5. Please give some information about the snow distribution and observation in this site since the soil-snow interaction is the topic of this paper. Only soil information was given here.

Response: We added some text about the snow characteristics in this region (see Section 2.5). As the snow observation is scarce and difficult to collect in this site, we describe the snow distribution referring to the winter precipitation characteristics and other meteorological data. Line 208-209, 212-215.

14. Line 158. The station in TP, with shallow snowpack, I strongly suggest considering the solar radiation penetration.

Response: In UEB model, when the snowpack is shallow, the albedo is weighted between the snow albedo and bare ground albedo $A_{v/ir} = r\alpha_{g,v/ir} + (1-r)\alpha_{v/ir}$. The weighting factor $r = \left(1-\frac{z}{h}\right)e^{-z/2h}$, in which the solar radiation penetration in the snow is exponentially attenuated as expressed by the exponential term. The incoming radiation is then altered and also the energy budget components.

We agree with your comments and the explicit consideration of the solar radiation penetration in the shallow snowpack and enriching the snowpack processes will be our next steps. See our revisions in Section 5.

15. RESULTS part. Where are the results on snow? Would you please give a quantitative evaluation of these results?

Response: We ran the simulation using the data from the Yakou super snow station in Qilian mountain. The comparisons of observed and STEMMUS-UEB simulated snow water equivalent dynamics were presented, together with the surface evaporation, soil moisture and temperature simulations. All the simulation results of the Yakou super snow station demonstrated the validity of STEMMUS-UEB model.

We added the site description in Section 2.5 and model results in Appendix B.

16. Line 319-321. It would be true in this region, but it would be evidently given here by using data, observation, references, and so on.

Response: We added the relevant case studies in Maqu (Li et al., 2017), which show that the snowpack is shallow and intermittent. On the other hand, it can be inferred from the less and temporal winter precipitation. See Section 4.1.

17. Figure 1. Please clearly present the coupling variables between UEB and STEMMUS-FT.

Response: Yes. The coupling variables were presented in the updated Figure 1. For the energy transfer, the variables are the ground heat conduction flux Q_g and the convective heat flux due to the snowmelt Q_m. For the presented cases, soil surface temperature was set as the topsoil energy boundary condition. For the mass transfer, the snowmelt water flow M_r is added on the soil surface as the coupling variable.

18. Figure 2. It is better to present the precipitation with columns but not lines. The color between precipitation and snow should be different. In addition, the improvement with the coupling snow module is not so noticeable.

Response: Yes. We replotted Figure 2 and presented the precipitation with columns.

For this simulation period, the precipitation/snowfall is intermittent and less. The total precipitation amount is only 6.1 mm. Nevertheless, the model with the snow module can well estimate the increase of surface albedo due to the presence of snowpack. The model without the snow module, however, presented no increase of surface albedo in response to the precipitation events.

The difference between models can be identified although it is not that noticeable as the snowfall is less and temporal.

19. Figures 3 and 4. The difference is tiny between two cases with and without snow modules.

Response: As the precipitation/snowfall is intermitted with less amount, the difference between the models with and without the snow module is indeed not that obvious. The difference between three cases with different soil physical processes is more significant here. It indicates that such amount of snowfall during this simulation period can only affect the hydrothermal regimes of the top sol layers and not enough to affect the deeper soil moisture and temperature dynamics.

On the other hand, we presented the results of soil moisture and temperature for Yakou station. The difference between the model with and without the snow module can be identified (Figure B4 and B5).

20. Figure 5. The improvement is not apparent from these results.

Response: The total precipitation during the simulation period is only 6.1 mm. The amount of snowfall and snow sublimation is thus not that much. Nevertheless, the difference between the model with and without snow module can be identified. The simulation of the cumulative LE was improved by the ACD and ACD-air models with the snow module. We added the additional plots in Figure 5, presenting the simulation bias (Simulation - Observation) for the model with and without the snow module, to make the improvement more visible.

To demonstrate the improvements using the model with and without snow module, we ran the simulations for the Yakou station (Figure B2 and B3). Surface evaporation was underestimated by the model without the snow module. Such underestimation was alleviated by the model with the snow module. Compared to the model without the snow module, the model with the snow module presented a closer correlation with the observed surface evaporation.

Figures and Tables

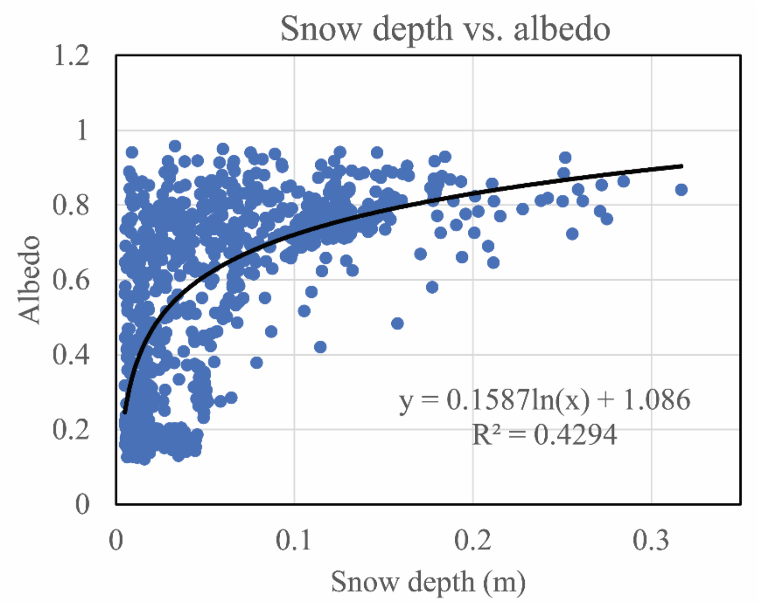

Figure R1. Scatter plot of the snow depth and albedo (Yakou station).

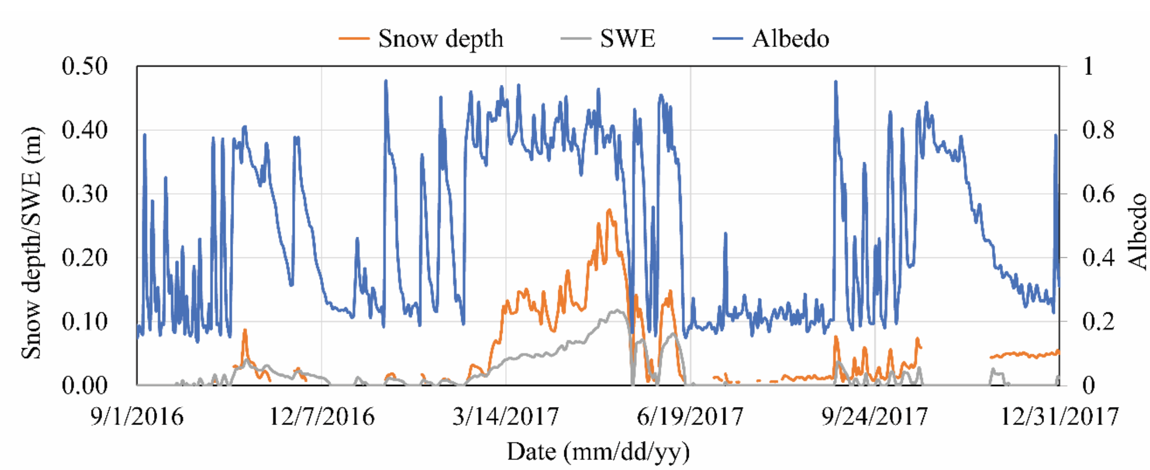

Figure R2. Time series of the snow depth, snow water equivalent (SWE), and albedo.

Three example periods were selected to illustrate the validity of using the indirect method, i.e., the albedo variation together with the ancillary meteorological data (air temperature Ta and precipitation), to identify the presence of snowpack and its lasting time (Table R1).

Table R1. The identification of snowpack using the direct evidence, i.e., the observed soil water equivalent (SWE, shaded with yellow color) and the indirect method, i.e., the albedo variation together with the ancillary meteorological data (air temperature Ta and precipitation) (shaded with blue color). The observed snow water equivalent is in 6-hour interval.

TIME	Ta (°C)	Precipitation (mm)	Albedo	SWE (mm)	Remarks
2016-10-10 12:30:00	-0.8	0	0.14		
2016-10-10 18:30:00	-1.59	0	0.36		
2016-10-11 00:30:00	-5.24	0			
2016-10-11 06:30:00	-6.73	0		10.90	
2016-10-11 12:30:00	-2.97	0.4	0.87	11.98	
2016-10-11 18:30:00	-4.02	0	0.99	13.42	First example period
2016-10-12 00:30:00	-4.44	0		15.42	
2016-10-12 06:30:00	-5.19	0		16.74	
2016-10-12 12:30:00	-3	0	0.62	17.22	
2016-10-12 18:30:00	-1.45	0	0.61	17.17	
2016-10-13 00:30:00	-2.84	0		16.30	
2016-10-13 06:30:00	-5.14	0		15.61	
2016-10-13 12:30:00	-0.37	0	0.18		
2017-01-28 12:30:00	-13.7	0	0.19		
2017-01-28 18:30:00	-14.32	0			
2017-01-29 00:30:00	-17.1	0			
2017-01-29 06:30:00	-15.15	0		2.51	
2017-01-29 12:30:00	-12.32	0	0.64	4.59	
2017-01-29 18:30:00	-9.76	0		6.69	
2017-01-30 00:30:00	-11.82	0		8.09	
2017-01-30 06:30:00	-12.68	0		9.26	
2017-01-30 12:30:00	-8.95	0	0.61	8.69	
2017-01-30 18:30:00	-9.58	0	0.95	8.31	
2017-01-31 00:30:00	-11.71	0		7.84	
2017-01-31 06:30:00	-13.47	0		7.01	Second example period
2017-01-31 12:30:00	-10.24	0	0.51	7.18	
2017-01-31 18:30:00	-9.76	0	0.85	6.40	
2017-02-01 00:30:00	-11.95	0		5.93	
2017-02-01 06:30:00	-15.5	0		4.75	
2017-02-01 12:30:00	-10.63	0	0.41	4.71	
2017-02-01 18:30:00	-8.66	0		5.86	
2017-02-02 00:30:00	-10.58	0		6.12	
2017-02-02 06:30:00	-12.15	0		5.85	
2017-02-02 12:30:00	-9.47	0	0.32	4.49	
2017-02-02 18:30:00	-8.17	0		3.82	
2017-02-03 00:30:00	-10.22	0		4.27	
2017-02-03 06:30:00	-12.4	0		4.27	

2017-02-03 12:30:00	-7.69	0	0.29	4.00	
2017-02-03 18:30:00	-7.73	0	0.23	4.06	
2017-02-04 00:30:00	-8.59	0		3.50	
2017-02-04 06:30:00	-8.37	0		2.08	
2017-02-04 12:30:00	-5.59	0	0.23		
2017-02-06 12:30:00	-2.91	0	0.19		
2017-02-06 18:30:00	-13.13	0	0.49		
2017-02-07 00:30:00	-17.7	0			
2017-02-07 06:30:00	-19.04	0			
2017-02-07 12:30:00	-16.09	0	0.30	1.90	
2017-02-07 18:30:00	-17.33	0	0.77	2.52	
2017-02-08 00:30:00	-18.17	0		3.54	
2017-02-08 06:30:00	-18.25	0		4.61	
2017-02-08 12:30:00	-13.95	0		5.73	
2017-02-08 18:30:00	-15.16	0	0.99	7.19	
2017-02-09 00:30:00	-17.3	0		7.44	
2017-02-09 06:30:00	-17.53	0		7.74	
2017-02-09 12:30:00	-13.56	0	0.65	7.91	
2017-02-09 18:30:00	-12.43	0		7.64	
2017-02-10 00:30:00	-16.64	0		8.12	
2017-02-10 06:30:00	-17.43	0		7.71	
2017-02-10 12:30:00	-16.36	0	0.87	5.99	
2017-02-10 18:30:00	-14.38	0		7.58	
2017-02-11 00:30:00	-16.07	0		8.05	Third example period
2017-02-11 06:30:00	-16.7	0		8.54	
2017-02-11 12:30:00	-11.54	0	0.61	8.92	
2017-02-11 18:30:00	-10.01	0		8.93	
2017-02-12 00:30:00	-13.76	0		8.27	
2017-02-12 06:30:00	-15.37	0		8.03	
2017-02-12 12:30:00	-9.63	0	0.59	7.02	
2017-02-12 18:30:00	-7.45	0	0.93	6.61	
2017-02-13 00:30:00	-9.27	0		6.37	
2017-02-13 06:30:00	-12.22	0		5.83	
2017-02-13 12:30:00	-7.75	0	0.51	5.71	
2017-02-13 18:30:00	-9.31	0	0.88	5.79	
2017-02-14 00:30:00	-11.14	0		5.61	
2017-02-14 06:30:00	-14.02	0		5.51	
2017-02-14 12:30:00	-8.78	0	0.46	5.55	
2017-02-14 18:30:00	-7.36	0		4.80	
2017-02-15 00:30:00	-10.56	0		4.61	
2017-02-15 06:30:00	-12.26	0		4.52	
2017-02-15 12:30:00	-7.71	0	0.37	3.99	
2017-02-15 18:30:00	-3.45	0	0.76	3.81	

2017-02-16 00:30:00	-6.3	0		2.03
2017-02-16 06:30:00	-7.07	0		2.62
2017-02-16 12:30:00	-9.74	0	0.29	2.33
2017-02-16 18:30:00	-10.48	0		1.78
2017-02-17 00:30:00	-10.66	0		1.88
2017-02-17 06:30:00	-10.74	0		2.05
2017-02-17 12:30:00	-7.3	0	0.25	2.12
2017-02-17 18:30:00	-4.69	0	0.57	
2017-02-18 00:30:00	-6.31	0		
2017-02-18 06:30:00	-8.64	0		1.26
2017-02-18 12:30:00	-5.53	0	0.21	

Reference

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