**Interactive comment on "Review of snow phenology in the Northern Hemisphere and its relationship with climate and vegetation" by Guo et al. Anonymous Referee #2**

There is a lot of good information in this paper. The authors have done a good job of researching the literature, especially as it relates to snow cover in China. They provide a short but nice review of remote sensing data products in Section 2.1.2 and in Table 2. Additionally, they address an important topic that deals with cyclic change in the Northern Hemisphere snow cover patterns, i.e., snow phenology, as it is related to climate change.

In the early part of the Introduction the authors should define 'snow phenology' so that the reader understands the exact meaning with respect to this paper. It is defined in the first sentence of the Abstract, but needs to be defined more clearly using proper English there. The words 'snow phenology' are used repeatedly throughout the manuscript, thus the authors need to ensure that the phrase is referred to in a consistent manner throughout and matches the exact definition that they need to add to the Introduction.

**Response:** Thank you for your suggestion. We also intended to define snow phenology in the abstract or introduction, but we did not find a clear definition in the previous papers.

Chen et al. (2021) described the snow phenology—'Snow cover phenology (SCP) variables including snow onset date (Do), snow end date (De), and snow duration days (Dd) are key indicators of seasonal variation of terrestrial snow cover over the NH and becoming increasingly valuable indicators of climate change.'

Notarnicola et al. (2020) described snow 'Changes in snow cover and related phenology (duration, onset and melt) have a critical role in mountain environment, and are strictly related to water availability in downstream areas.'

We have checked and ensured that the snow phenology, snow cover onset date (SCOD), snow cover end date (SCED) and snow cover days (SCD) are referred to in a consistent manner throughout the article.

I am not clear about whether this review paper belongs in The Cryosphere. Perhaps the authors could re-focus the paper on snow cover on the Tibetan Plateau?? I don't think they have done a

thorough job addressing snow cover in the entire Northern Hemisphere.

**Response:** Throughout the article, the data and analysis of snow phenology we presented are based on the Northern Hemisphere, not the Tibetan Plateau. In section 3, we display the distribution of snow phenology over the Northern Hemisphere from 1972 to 2020 based on NHSCE snow cover data, interannual variations over NA/EU/NH and the corresponding contributions to NH from EU and NA (NA, EU and NH represent Eurasia, North America and the Northern Hemisphere, respectively). In section 4, we also focused on analyzing the interrelationships among snow phenology and temperature, atmospheric circulation, and vegetation at the scale of the Northern Hemisphere. For example, we mentioned in section 4.1 (revised version) that 'Studies have found that anomalous changes in winter snow cover may cause an anomaly in East Asian monsoon circulation over Eurasia (Chen and Sun, 2003; Chen et al., 2003), and spring Eurasian snow will affect the Indian summer monsoon through land–sea thermal differences and atmospheric circulation (Halder and Dirmeyer, 2017)'.

Do we really need all of those remote sensing products to address the snow phenology questions? It almost seems like there are two papers here – one that reviews remote sensing products and another that addresses the snow phenology question.

**Response:** At present, there are many data available for snow cover research, and we can use a multi-dataset approach to map snow cover over the NH because it exploits the strengths of the various platforms and methodologies. Analysis of multiple datasets or an ensemble product helps to overcome the limitations of individual datasets. Brown (2010) conducted a multi-data set analysis of variability and change in Arctic snow cover, examined the consistency of Arctic snow cover products, and provided estimates of the uncertainty in snow cover extent.

Therefore, it is important to be familiar with a variety of remote sensing products to address snow phenology questions. The snow cover product is the basis for obtaining snow phenology. Only by obtaining accurate snow phenology information can we correctly understand the relationship between climate change and snow.

Work is needed to improve the English in this paper. Overall it is acceptable but there are many places that need work. I only mentioned a few, below, though there are many other places that need

improvement in the English on every page.

**Response:** We will have the paper polished by a native English speaking professional editor.

The authors should consider removing the word 'variation' from the title, and perhaps replacing it with the word 'literature,' because you cannot review variation

**Response:** Thank you for your opinion. Indeed, 'variation' is not appropriate here.

**The title was changed as follows:**

Review of snow phenology in the Northern Hemisphere and its relationship with climate and vegetation

Specific comments:

Line

36 delete: "which significantly affects Earth's climate change."

**Response:** We have deleted this sentence.

54 the Warren references is in appropriate here since climate change was not really written about much in 1982.

**Response:** For the quotation of this paragraph---'snow phenology plays an important feedback role in climate change through its characteristics of high reflectivity and low thermal conductivity', we have added new references (Ke et al., 2016; Notarnicola et al., 2020), which describe snow phenology as playing an important role in climate change.

Table 1 and write-up preceding the table: what about snow depth datasets in the United States?

**Response:** The statistical content of Table 1 was referred from Peng et al. (2013), and the snow depth dataset in the United States can be freely obtained from GHCN. We can obtain the day, month, and year of interest for snow depth observation data from GHCN stations, which is accessible at **https://www.ncei.noaa.gov/access/monitoring/daily-snow/AK/snow-depth/ 20230201.**

102 Passive microwave products do not have very good accuracy for mapping snow, snow depth and SWE

**Response:** For the description of passive microwave data, we added the following sentence. The corresponding reference was added. In this reference, it described that due to topographic and land cover heterogeneity, spatial variability in SWE derived from passive microwave satellite measurements is not adequately captured. Coarse resolution is a particularly critical limitation in alpine regions, which are masked out completely in some products.

**Added the sentence as follows:**

however, it does not have good accuracy for mapping snow cover due to the rough resolution (Mortimer et al., 2020)

105 the word "influential" is not appropriate in this context

**Response:** This sentence was revised as follows:

Global Snow Monitoring for Climate Research (Globsnow), which was released by the European Space Agency in 1979, is a daily global SWE dataset with a spatial resolution of 25 km (Lin et al., 2020).

112 what is "L1R?"

**Response:** L1R means Level-1R. AMSR2 Level-1R (L1R) input brightness temperatures that are calibrated, or unified, across the JAXA AMSR-E and JAXA AMSR2 L1R products.

We went to the website to obtain the AMSR-E/AMSR2 and were surprised to find that the description of data is now 'This AMSR-E/AMSR2 Unified Level-3 (L3) dataset provides daily estimates of Snow Water Equivalent (SWE)'.

**we modified the original sentence as follows:**

The Advanced Microwave Scanning Radiometer2 (AMSR2) onboard the GCOM-W1 satellite was launched in 2012 as a follow-up product to AMSR-E, and the daily SWE data can be derived from AMSR2 L3 (Tedesco and Jeyaratnam, 2019).

Table 2: all of the MODIS products are global, including MOD10A1, MOD10A2, MOD10C2 and MOD10CM; also all of the MODIS products extend from 2000-present.

**Response:** On the MODIS website, we further confirmed that the MOD10A1, MOD10A2, MOD10C1, MOD10C2 and MOD10CM products are global and extend from 2000-present.

However, not all MODIS products start in 2000; for example, MYD10A1, MYD10A2, and MYD10C2, which were carried on the Aqua satellite, extend from 2002-present.

183 and 211 the word “plain” should read “plains”

**Response:** Thank you for your comments, and we have modified these words.

200 delete the word “significantly”

**Response:** Thank you for your comments, and we have deleted this word.

Figure 2: please provide a reference for the caption; where has this analysis been published?

**Response:** Figure 2 shows our own statistical results using NHSCE data, rather than referring to other papers.

241 over what time period has the snow cover extent in the Arctic decreased?

**Response:** My apologies, perhaps I did not express it clearly. What I meant to say was the impact of temperature rise on the Arctic snow cover extent, rather than describing a decrease in the Arctic snow cover extent over a certain period of time. We have rephrased the original text.

**The sentence now reads as follows:**

It has been found that when the temperature increases by 1 ℃, the average SCED advances by 1.6±1.8 days (Peng et al., 2013), and the snow cover extent in the Arctic decreases by $7\times10^5$-$8\times10^5$ $km^2$ (Derksen and Brown, 2012).

333 delete the word “organic”

**Response:** Thank you for your comments, and we have deleted this word.

352-354 I am not quite sure what this sentence means??

**Response:** We apologize that we did not describe the meaning of this sentence clearly.

**We have rephrased this sentence to read:**

The response mechanism between snow phenology variation and global climate change is not clarified in the Northern Hemisphere, and the reasons for regional differences in snow phenology

variation have not been clearly analyzed. For example, Figure 2b shows that the SCED in North America is later than that in Eurasia. We speculated that this phenomenon might be related to the atmospheric circulation pattern according to previous studies, but there is no relevant research evidence.

**Added references are as follows:**

Ke, C.Q., Li, X.C., Xie, H., Ma, D.H., Liu, X and Kou, C.: Variability in snow cover phenology in China from 1952 to 2010, Hydrol. Earth. Syst. Sci., 20:755–770, doi:10.5194/hess-20-755-2016, 2016.

Mortimer, C., Mudryk, L., Derksen, C., Luojus, K., Brown, R., Kelly, R and Tedesco, M.: Evaluation of long-term Northern Hemisphere snow water equivalent products, Cryosphere., 14, 1579–1594, doi: 10.5194/tc-14-1579-2020, 2020.

Notarnicola, C.: Hotspots of snow cover changes in global mountain regions over 2000–2018, Remote. Sens. Environ., 243, 111781. doi: 10.1016/j.rse.2020.111781, 2020.

Tedesco, M. and J. Jeyaratnam. (2019). AMSR-E/AMSR2 Unified L3 Global Daily 25 km EASE-Grid Snow Water Equivalent, Version 1 [Data Set]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/8AE2ILXB5SM6.