Response to Referee #1's comments

Authors responses are shown in bold font.

Authors: We would like to thank both referees for their helpful and constructive comments and thorough reviews. We have improved the flow of the paper and added more information about the VIIRS snow maps and quantitative comparisons between the new MODIS and VIIRS cloud-gap filled snow maps. We have emphasized the novelty of the work as requested by both referees. We have also re-stated our objectives as requested by both referees, and changed the title to better reflect the content of the paper.

Referee #1

Referee: General comments
The objective of this work is to describe algorithm for removal clouds in MODIS (Terra and Aqua) and VIIRS snow cover products. The aim is to develop/describe a method, which will generate cloud-free images of MODIS and VIIRS in operational practice.

Authors: We now have improved our statement of objectives. We do not develop a method in this paper because the method has already been developed. We now more clearly state our objective as follows:
"The objective of this paper is to introduce the new MODIS and VIIRS standard CGF daily SCE products and to provide preliminary evaluation of uncertainties in the gap-filling methodology so the products can be used as the basis for a moderate-resolution Earth Science Data Record (ESDR) of SCE."

Referee: The topic of the study is for sure within the scope of the journal. The manuscript reads well, however, significant novel scientific contribution is not clearly formulated nor demonstrated. It is not clear in which respect is described cloud filling method new, compared to existing approach.

Authors: We now describe clearly the novelty of this work as compared to earlier work (e.g., Hall et al., 2010). The Hall et al. (2010) paper described a gap-filling technique, but the basic technique outlined in that paper was not implemented until recently. And the algorithms that have been implemented are much more complex than the one described in Hall et al. (2010).

We introduce the CGF products derived from the MODIS and S-NPP VIIRS. These products have not been introduced previously in the peer-reviewed literature. In the present paper, we describe new cloud-gap filled (CGF) MODIS and VIIRS algorithms and products (targeting hydrologists, climate scientists and modelers) that will become available to the scientific community in the fall of 2019. These products include quality-assurance (QA) information that can be manipulated by a user to develop a unique product that can be tuned to a user's particular study area. This new and unique capability has not

been possible using earlier MODIS snow products. Uncertainties of the products are addressed in terms of their use in the hydrological community.

Also new is the finding that the Terra MODIS CGF snow product is superior to the Aqua MODIS CGF snow product, and the reason for this is discussed in the revised paper. Following on from this, we make the case that an Earth Science Data Record (ESDR) can be developed to begin in 2000 using Terra MODIS data, and continue through the present and beyond using VIIRS and JPSS data.

Additionally, new comparisons between the Terra MODIS and S-NPP VIIRS CGF snow products have been added: the comparisons are performed for a time series consisting of three months in the winter/spring of 2012. We have not previously published Terra MODIS vs. S-NPP CGF snow-map comparisons in the peer-reviewed literature. Furthermore, we are not aware of anyone else doing such comparisons. A new Figure 9 has been added as shown below:

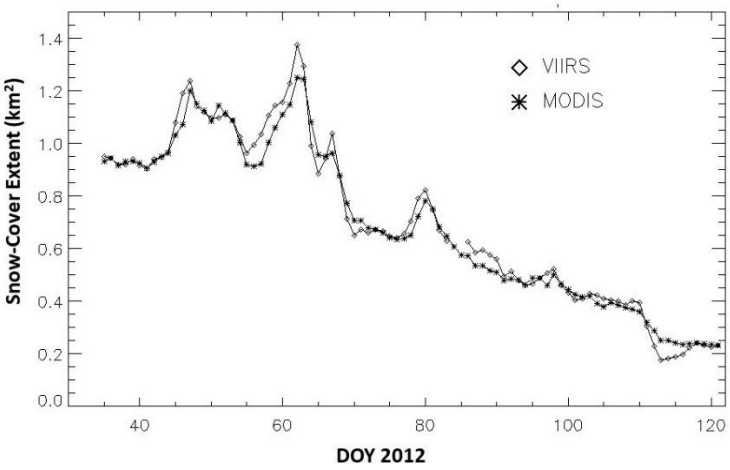

Figure 9: Time series showing differences in snow-cover extent (SCE) derived from Terra MODIS and S-NPP VIIRS cloud-gap filled (CGF) snow maps for a nearly 3-month period extending from 4 February – 30 April 2012. Though the time series began on 1 February, snow-cover extent from 1 – 3 February snow cover is not shown because, in this example, the gap-filling algorithm was started on 1 February had not filled most of the gaps from clouds until 4 February.

Figure 2 has been revised to demonstrate differences/similarities between the MODIS and VIIRS snow-cover products. See below.

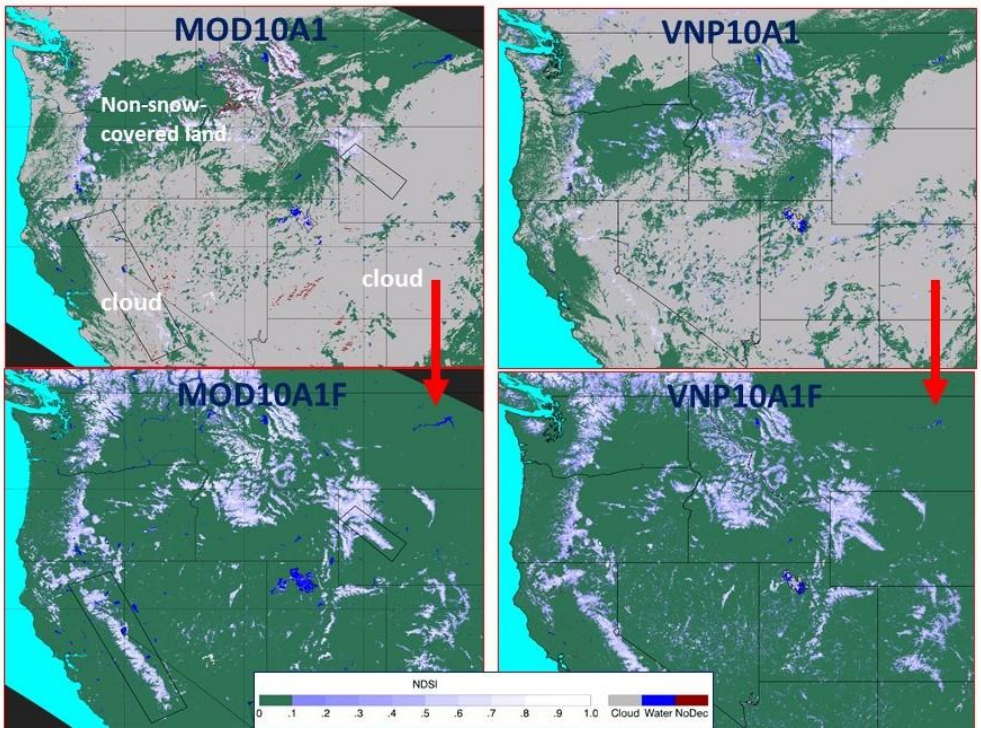

Figure 2: Examples of MODIS and VIIRS standard and cloud-gap filled (CGF) snow maps on 14 April 2012 for a study area in the western United States/southwestern Canada (see **Fig. 1**). **Top left**: MODIS MOD10A1 C6.1 snow map showing extensive cloud cover on 14 April 2012. **Top right**: VIIRS VNP10A1 C1 snow map also showing extensive cloud cover on 14 April 2012. **Bottom left**: MOD10A1F C6.1 CGF map corresponding to the MOD10A1 snow map in the top row, also for 14 April 2012. **Bottom right**: VNP10A1F CGF map corresponding to the VNP10A1 snow map in the top row, also for 14 April 2012. In all of the snow maps, non-snow-covered land is green. Regions of interest containing the Sierra Nevada Mountains in California and Nevada (109,575 km^2), and the Wind River Range in Wyoming (22,171 km^2), are outlined in red on the MODIS snow maps. The following MODIS tiles were used to develop the MODIS composites: h08v04, h09v04, h10v04, h08v05, h09v05, h10v05. Each VIIRS swath that included coverage of this study area was composited to create a daily map, then the daily maps were used to create the VNP10A1F snow map for 14 April 2012.

The following findings are new:

- **Differences in cloud masking between MODIS and VIIRS affect the snow map results of both the standard product and the new CGF snow maps;**
- **Differences in cloud masking between the Terra MODIS and the Aqua MODIS affect the snow map results of both the standard product and the new CGF snow maps;**
- **The Terra MODIS snow maps are superior to the Aqua MODIS snow maps in C6 and C6.1;**
- **Development of an Earth Science Data Record that uses Terra MODIS and S-NPP VIIRS CGF snow maps is introduced.**

In earlier work (e.g., Hall et al., 2010), we described a methodology that would provide daily, cloud-free snow maps globally using a gap-filling method with the daily climate modeling grid (CMG) composited products at 5-km resolution. Subsequent work (e.g., Hall et al. 2015) demonstrated the utility of this method applied to the daily tiled products for a study area in the Wind River Range of Wyoming. This gap-filling method, described in Hall et al. (2010), has been adopted as the basic algorithm of the standard product, M*D10A1F, using the daily gridded products of individual observations at 500 m resolution and including *many* enhancements to the basic algorithm that was described in Hall et al. (2010).

In short, this paper is very timely because MODIS C6.1 and VIIRS C2 products are due to become available during the fall of 2019 and there is a great deal of information in this paper, especially in its revised form, that will be useful to users of the products.

Referee: The idea of providing VIIRS snow cover product as alternative to MODIS is interesting, however the manuscript in its current form provide only very limited quantitative evaluation of the new features of presented method, about accuracy and comparison between the products (MODIS, VIIRS) and differences in the efficiency of gap-filling method for these two (MODIS and VIIRS) products. This is the main limitation of the (current form of) study and this is the main reasons for recommending a substantial revision of the manuscript.

Authors: We appreciate this salient comment and have added quantitative evaluation of the Terra MODIS vs. S-NPP VIIRS CGF products. We developed a time series for a three-month period in the winter/spring of 2012. Please see revised Figure 2 and new Figure 9. Results show that the products agree well, though the VIIRS CGF maps show slightly more snow cover than do the Terra MODIS CGF maps. This is probably due to the fact that the VIIRS maps show fewer clouds than the Terra MODIS CGF maps show.

Referee's specific comments:
Referee: 1) Abstract: l.27-28: " work is ongoing: : :". It will be interesting to see the results of such evaluation in the study. Otherwise the sentence is not very informative for the readers.

Authors: We agree with this comment and have improved the wording in the abstract of the revised paper. We have now done additional work to quantify some of the uncertainties in the products, including some potential uncertainties in an ESDR that will use both the Terra MODIS and the S-NPP VIIRS.

Referee: 2) The study proposes VIIRS products to be an alternative to MODIS, but the cloud removal is presented only for MODIS. A thorough comparison with VIIRS will be interesting to see.

Authors: We cannot provide a thorough comparison of MODIS CGF and VIIRS CGF because the products are not yet available to download from NSIDC. Using swath data, however, we created a time series of MODIS CGF products for 2012. And, to address this

comment, we have recently created a 3-month time series of VIIRS cloud-gap filled snow-cover extent (SCE) products and have plotted them along with the daily values (in km^2) with the Terra MODIS CGF. This is shown in the new Figure 9, above. Cloud cover on a single MODIS and VIIRS scene comparison is also shown in the revised Figure 2.

Furthermore, the revised Figure 3, shown below, demonstrates that the VIIRS product starts out with fewer clouds than does the Terra MODIS product, and clears the clouds faster according to the CGF algorithm.

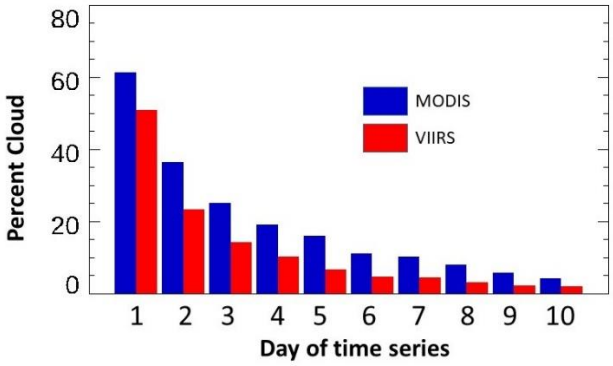

Figure 3: Percent cloud cover in a Terra MODIS (MOD10A1F) and an S-NPP VIIRS (VNP10A1F) time series of snow-cover maps for the western United States study area (see location in Fig. 1). Note that the percentage of cloud cover decreases dramatically in the first few days following the 4 February 2012 initiation of the CGF time series, denoted here as Day 1.

Creating time series before availability of the products through NSIDC (to occur in the fall of 2019) is computationally intensive. This is the reason that we have not created multiple long time series.

The bottom line is that it is not possible for us to perform a thorough comparison, but we now include a graph showing a comparison of three months of both MODIS and VIIRS CGF daily snow maps. The comparisons also demonstrate a great amount of agreement in SCE between the MODIS and VIIRS CGFs which is desirable for development of an ESDR. This is quantified for the time period shown.

Referee: 3) The novelty of the objectives is not clearly formulated. The wording as "to describe: : :", "to discuss: : :" does not clearly indicate quantitative contribution of the study.

Authors: We have improved the description of the clarity of the objectives. As also provided above, the following revised statement of our objectives appears in the Abstract and in the Introduction:
"The objective of this paper is to introduce the new MODIS and VIIRS standard CGF daily SCE products and to provide preliminary evaluation of uncertainties in the gap-filling methodology so the products can be used as the basis for a moderate-resolution Earth Science Data Record (ESDR) of SCE."

Referee: 4) Section 2.4: this section is interesting and shows different methods used for cloud removal in the past. However some organised synthesis of the approaches will be useful here. E.g. stratification of approaches according to different assumptions (e.g. temporal, spatial filters, snow line, multi-sensor combination, etc.).

Authors: We have greatly shorted this section based on this comment. Since the CGF method to provide daily, cloud-free SCE maps for MODIS and VIIRS has already been determined and the products are starting to be produced (final production and release will begin in the fall of 2019), other cloud-clearing methods are somewhat irrelevant to the present work. However, we don't want to ignore other work that has been done to create daily cloud-reduced or cloud-free snow maps because there are many effective and novel cloud-clearing methods and much work has been done. Other works detailing methods that are also very useful for cloud clearing are important and are still cited though the entire section has been shortened. The organization of this section has been vastly improved.

Referee: 5) Why only temporal filter is considered for gap-filling method? During snowmelt, snow-line approach or some kind of spatial filter can be more efficient.

Authors: There are many other useful methods of gap filling, but the method described in our paper is the method that is used to develop the new product that will be available starting this summer or fall. We are beyond the point where different methods can be considered since the new algorithm uses the CGF method, all of the programming has been completed by the MODIS Project and the products will be available soon. It is too late to change the algorithm for Collection 6.1.

Referee: 6) The results show only few examples which does not allow to see clearly if the results are robust and general. More thorough analysis (longer time periods, seasonal evaluation, larger/different regions) will allow to draw much more robust findings.

Authors: We agree with this comment, but we are unable to do a thorough and global analysis because the product is not yet being produced by the MODIS and VIIRS Projects. When processing starts, the product will be downloadable through the National Snow and Ice Data Center starting in the fall of 2019.

In order to develop a time series in this pre-production phase, we need to do a considerable amount of programming. We've done this by developing a Terra MODIS CGF SCE time series for the western U.S. data set for 2012. For this revised version of the paper, and in response to this and other comments, we ran a 3-month time series using VIIRS SCE maps (see Figure 9). Running a CGF time series is computationally burdensome, and therefore a comprehensive, global analysis cannot be accomplished until after the official MODIS processing begins. Even after production begins it will take many months until the complete MODIS and VIIRS time series (from 2000 to present for MODIS and from 2011 to present for VIIRS) can be processed. Complete processing is likely to occur sometime in the year 2020 for both the MODIS C6.1 and VIIRS C2 CGF SCE products.

In short, processing will not be complete in a time frame that is reasonable for providing the revisions to this paper. And it is important that this paper be published so that users of the new products will have the information contained in this paper when the products first become downloadable from NSIDC in the fall of 2019.