Response to Reviewers’ Comments

*First please allow us to express our deep thanks to all reviewers. This manuscript benefits significantly from their constructive comments and critiques. We have strived to address every issue that has been raised by the reviewers. Detailed responses are listed below.*

***Reviewer #1 (Remarks to the Author):***GENERALThis review paper covers contributions of satellite remote sensing (SRS) studies to climate change science. A collection of this kind is likely to be of general interest to the readership of Nature Climate Change, provided that it either presents a complete overview of the field, or specifically focuses on progress in a given sub-field. In its current form, the manuscript provides an overview of some areas, and leaves out others (precipitation, trace gases) "due to the page limitation"; this appears somewhat arbitrary. On the whole, the paper is well-structured and could be developed into a valuable collection of information on the field. I suggest the following improvements:

***Response:*** *Thank the reviewer for the encouraging comment. Here we like to expand on the reasons listed in the manuscript for our choice of reviewing subjects. In the past five decades, progresses in remote sensing have made it an important tool for observing the climate system. However, remote sensing scientists largely focus on their own specific sub-fields and seldom discuss the overall role of remote sensing in climate change studies. The question that has not been well answered is: do progresses in our field help to improve fundamental understanding of the climate change. With this question and the interdisciplinary feature of Nature Climate Change in mind, we started the discussion of the suitable topics for this review two years ago. After extensive surveys of literature and media reports and rounds of revisions, we have come down to the current list which includes climate warming, change of snow and ice cover, sea level change, and the forcing and feedback of climate change. Skeptics of climate change often challenge the findings and theories in these fields. Interestingly, remote sensing data were frequently cited to support these challenges. For examples, In “Himalayan glaciers have lost no ice in the past 10 years, new study reveals” (Fox News on 10 February, 2012), the GRACE satellite data was cited. “New NASA data blow gaping hole in global warming alarmism” (Forbes on 27 July, 2011) cited the ERBS and TERRA satellite data. Therefore, instead of conducting a comprehensive review of the entire field, or a review focused on one specific parameter, we decided to focus on those key research questions from a remote sensing perspective. We are aware of the limitation of this short review. A full account of the role of remote sensing in climate change studies can only succeed with a much longer and more comprehensive analysis of literature. Nevertheless we believe that the choice of topics in this article can meet our goal of revealing the major contributions and limitations of satellite remote sensing in climate change studies. Also, the amount of information contained in this article will not make it incomprehensible to the wider climate research community.*

1: Scope  
- A discussion of the role of SRS of precipitation amounts and changes would be very valuable. There has been a lively debate on (apparent) disagreements between GCMs and satellite observations of precipitation in the last three years. This should certainly be included here. (cf. Wentz et al., 2007, How much more rain will global warming bring? Science, 317:233-235; and the discussion that followed on this paper). In the appendix, precipitation data sets are listed. The omission of precipitation from the paper appears illogical.

***Response:*** *We enhanced the discussion on SRS of water vapor and added one paragraph on precipitation. (Page 15-18). We adopted the suggested citation (Wentz et al., 2007) and used it to open a discussion on the discrepancy of modeled and observed precipitations.*

- The discussion of the individual areas of SRS-provided insights focuses mostly on trends and absolute amounts/levels. Insights into climate system processes on the other hand seem to be somewhat under-represented. What potentials and limitations exist in this field?

***Response:*** *In the revised manuscript, we added discussion on potential contributions of SRS on understanding climate system processes in each topic. E.g., the control of stratospheric water vapor concentrations by tropical tropopause temperature (Page 16, p1). We also added discussion on the limitation of SRS in revealing climate system processes in the manuscript. (Page 19, Paragraph 2)*

- The literature cited is not always up to date. In particular, when other review articles are cited, these are sometimes superseded by others by now (see specifics below).

***Response:*** *We wanted to cite the paper where an idea or a conclusion was first mentioned. This practice perhaps gives the impression that the cited literature is not always up to date. We examined the references suggested by the reviewer. If the new publication made significant progress on a topic of this review, we replaced the old reference. If the authors of the later paper only reaffirmed other’s idea with a longer time series, we kept the older reference. We tried to maintain a balance of the originality of the idea and the freshness of the citations. We also updated the rest references by following the same principle.*

- The main instrument/sensor type (passive/active, spectral region) used for each application should be given in the text, as is done for sea ice/ice sheet extent, for instance.

***Response:*** *We added main instrument/sensor type used for each application into the text.*

2: Coherence  
- In the introduction, the goal of presenting cases where SRS results led to result confirmations and/or falsifications is stated. This motivation is not pursued consistently in the article. Ice sheet mass results, as one example, are not put into the context of models or process insights.

***Response:*** *We made necessary revision to make all discussion following the same structure. SRS of ice sheet mass show that the ice-ocean interaction is a main cause of recent mass loss in Antarctic and Greenland. (Page 9, p1)*

- While the general structure of the article is well-suited to the purpose, more clarity is needed, in particular in the introduction. Processes, trends, variability are mixed up and need to be clearly separated throughout the article. How is SRS used to improve process understanding? What information do we gain about absolute levels and trends of/in parameters? In some parts, more specific information is needed; see remarks below.  
***Response:*** *We clarified the differences between discovering trends and variability in our discussion. We added comments on how SRS is used to improve process understanding. We also emphasized the progresses made on the understanding of absolute levels and trends of/in parameters. Detailed response are listed below.*

DETAILS  
("para": paragraph)  
== Abstract ==  
P2:  
- "were missed by climate models" - what does this mean? Processes that cannot be captured in models? Please be a little more precise here.

***Response:*** *We revised abstract and removed this sentence for better clarity. (Page 2)*

- "...are needed in future work AND FUTURE SYSTEMS to fully"

***Response:*** *“and future systems” were added as suggested.(Page2)*

P3:  
- observation of STATES and processes... at multiple SPATIAL AND TEMPORAL scales"

***Response:*** *Modified as suggested. (Page 3, p2)*

- produce climate projections -> inform climate projections (sat data does not directly "produce" projections)

***Response:*** *Modified as suggested. (Page 3, p2)*

- for reanalysis data, you only cite a source for NCEP. For ECMWF, the following is commonly used: Uppala, S., et al., 2005: The ERA-40 re-analysis. Quart. J. R. Meteorol. Soc., 131, 2961-3012.

***Response:*** *We dropped the ECMWF to cut down the word count of the paper. The change did not change the meaning of the sentence. (Page 3, p2)*

P4:  
- "uncertainties because of sensors and retrieving procedures" - more specific information is needed here.

***Response:*** *The sentence was revised as “biases in sensors and data retrieval algorithms”. Detailed discussions on these biases are given in the limitation section. (Page 4, p1)*

P4:  
- "SRS has greatly enhanced our understanding ..."  
a) "variations" remains unclear  
b) sentence appears redundant

***Response:*** *The sentence was removed. (Page 4, p3)*

- "This trend was first identified... have been adopted" - Not very relevant. Shorten, maybe combine into one sentence.

***Response:*** *The two sentences were combined into one. “This trend was first identified through analyzing anomalies in time series of near- surface air temperature over the land recorded by weather stations and was consistently challenged due to the biases in weather records”. (Page 4, p4)*

P5:  
- temperatures. I am somewhat worried about the fact that air temperatures and surface temperatures are mixed up here. Please  
a) explain why and how this is possible  
b) clearly state which is which and how they are related

***Response:*** *The distinctions between surface temperature and air temperature were clearly stated out in the revised manuscript. We changed the “global near surface air temperature data” to “near-surface air temperature data over the land” and added “the ocean surface and the atmospheric temperature”. (Page 5, p1)*

- "The surface temperatures of the global oceans..." - The mixture of ground-based and satellite data presented here is somewhat confusing. Please clarify this paragraph.

***Response:*** *We removed the sentence since the reconstruction method was not the focus of this paper. (Page 5, p2)*

- what is meant by "more steadily" rising SSTs?

***Response:*** *We changed the sentence to “the warming trend is the highest in the middle latitudes of both hemispheres” and removed the old sentence. The change reflected a more certain observation. (Page 5, p2)*

- what is a "horizontal zonal" gradient?  
***Response:*** *We modified the sentence as “Stronger east-to-west zonal SST gradients…” to explain the meaning of a “horizontal zonal gradient”. (Page5, p2)*

- "data sets suffer from poor spatial and temporal sampling" - are these really problems when assembling global trends? What is the effect of spatial resolution on results? Do we need high temporal resolution for multi-year time series? I doubt it.

***Response:*** *We modified the sentence as “While the overall warming trend has been confirmed, the magnitude of the detected trend has considerable uncertainty. Correction procedures supported by validation data from a dense in situ network are needed to reduce the level of uncertainty”. (Page5, p2) Also we agreed that temporal resolution is not an accurate expression here. Temporal frequency of coverage will be the main problem for studying climate trend. We added a discussion of this in limitations. (Page 19, p2)*

- "Improved satellite sensors ..." - Will not help for past time series.  
***Response:*** *We made revision as above so this is no longer an issue.*

P6:  
== Snow and ice ==  
- The retreat of snow and ice covers is an important...  
- Melting of snow and ice cover can cause ...

***Response:*** *Modified as suggested. (Page 7, p1)*

P7:  
- "These differences suggest..." - This sentence appears somewhat trivial: Of course it's the regional temperature, and not the global mean, that determines SCE.

***Response:*** *The sentence was removed and a short phrase was added to an earlier sentence to emphasize the influence of regional climate variability on SCE. (Page 7, p2)*

P8:  
- Whether or not the Arctic has reached/will reach a tipping point is a matter of debate. This should be mentioned.

***Response:*** *The sentence was modified to reflect the reviewer’s comment. (Page 8, p1)*

- last para: "... may be less than predicted in certain regions."

***Response:*** *Modified as suggested. (Page 9, p2)*

P9:  
- Some of these time series are very short - can these results be of general validity?

***Response:*** *We listed these studies to make a point that retreat of glaciers in high-altitude regions does not follow a uniform pattern but show strong regional variations. Therefore, even the time series is short; they did show that the variations happened.*

== Sea level rise ==  
- I suggest using "sea level change" or only "sea level" instead of "sea level rise", in consistency with the other chapter headings, which also do not include tendencies

***Response:*** *Totally agree, modified to sea level change.*

P10:  
- "while the minimum SLR was observed in the eastern Pacific"  
-> "such as" appears meaningless  
-> if this is the minimum, it MUST be (s)lower than the global mean.

***Response:*** *The sentence has been changed to “while slower than the global average SLR and even slightly negative trend were observed in the eastern Pacific”. (Page 10, p1)*

- beginning second para: "Questions have been raised..." - references needed

***Response:*** *We modified the sentence to “The significant acceleration of SLR in the satellite altimetry era has called for explanation of causes.”. One reference was also citied. (Page 10, p1)*

P11:  
- "... still elusive". Why?

***Response:*** *The term was changed to “still challenging”. The reasons are given in the followed sentences, mainly due to the mixture of inter-annual and decadal variability with long-term trend. (Page 11, p2)*

- "... zone are not covered..." - What is your suggestion to remedy this?

***Response:*** *We added one citation (Prandi, 2012) to answer this question. A partial solution for this question may be readily available but a total solution is still lacking. (Page 11, p2)*

== Solar radiation ==  
- reference 58 is 14 years old; also you speak of "most studies", suggesting more than one reference. Please provide

***Response:*** *This paragraph was revised. Newer citations are used (Hansen and Lebedeff, 2007; Scafetta and West, 2006; Benestad and Schmidt, 2009). (Page 12, p1)*

P12:  
== Aerosols ==  
- Aerosols do not as such affect climate sensitivity (which is defined as a temperature reaction to a doubling of CO2). They can however counteract greenhouse-gas-driven warming

***Response:*** *We thought that this is a matter of different interpretation of the definitions of climate sensitivity. According to IPCC AR4 8.6.1: “Climate sensitivity is a metric used to characterize the response of the global climate system to a given forcing. It is broadly defined as the equilibrium global mean surface temperature change following a doubling of atmospheric CO2 concentration”. Aerosols can produce important climate forcing. In that sense, it can modify the climate sensitivity. In order to remove the potential ambiguity, we modified our discussion to “…counteract the warming effects of anthropogenic greenhouse gases” and removed “climate sensitivity”. (Page 13, p1)*

- A fairly recent review of aerosol effects was given in Stevens, Bjorn and Graham Feingold, 2009: Untangling aerosol effects on clouds and precipitation in a buffered system. Nature, 461, 607-613.

***Response:*** *We revised the paragraph. (de Meij et al., 2012) was used. (Page 13, p1)*

P13:   
- "Earlier progress..." - a more up-to-date reference: Kokhanovsky et al., 2010, The inter-comparison of major satellite aerosol retrieval algorithms using simulated intensity and polarization characteristics of reflected light, Atmos. Meas. Tech., 3, 909-932.

***Response:*** *We revised the paragraph entirely and this sentence has been removed. We focused more on the recent progresses. (Page 13, p1)*

- "... data sets since 2000 show..." - Significantly longer time series are presented here: Cermak et al., 2010, Consistency of global satellite-derived aerosol and cloud data sets with recent brightening observations, GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L21704  
***Response:*** *We removed Zhang et al. 2010 from the reference list and used the suggested Cermak et al. 2010 since the later extended the analysis back to 1982. (Page 13, p1)*

== Clouds ==  
P15:  
- "... need to be improved in areas such as temporal sampling frequency and accuracy"  
- what do you mean by "such as" - what other important areas are there?

***Response:*** *We revised the paragraph significantly and a new citation (Taylor, 2012) was used to explain the major problem for detecting long-term trend of cloud properties. (Page 15, p1)*

- how would temporal sampling frequency improve observations?

***Response:*** *We revised the paragraph to focus more narrowly on the accuracy of cloud products. (Page 15, p1)*

- what is the problem with current accuracy? Accuracy with respect to what?

***Response:*** *The current accuracy is not adequate for detecting trend of cloud properties. That accuracy refers to the accuracy of product. All these points were made clear in the article. (Page 15, p1)*

== Water vapour ==  
- This part is significantly shorter than the others. Do you consider it less important or is there less insight? Less controversy?

***Response:*** *We added new contents to enhance the discussion of water vapor. Water vapor is the strongest greenhouse gas but its role in climate change is less controversy as other atmospheric constituents. (Page 15-16)*

P16:  
== Limitations of srs ==  
- I would not say there is a "lack of calibration" - rather, there may be errors in calibration due to various reasons

***Response:*** *The lack of calibration is a problem with early generations of satellites. For example, operational meteorological satellites generally lack reliable onboard calibration systems for solar-imaging channels so their observations have to be compared with reference sources (Minnis et al, 2002). In order to avoid confusion, we removed the sentence and rewrite the paragraph (Page 20, p1).*

- In the individual chapters before you mentioned temporal and spatial resolutions as possible problems. Do you see these as less important or do you include them in "limitations of sensors"?

***Response:*** *The importance of spatial and temporal resolutions is more dependent on the specific application. Other limitations discussed in the paper are more cross-board issues.*

- "Climate change studies commonly... and they indicated..." - This sentence appears a bit unclear. Who are "they"?

***Response:*** *We rewrote the whole paragraph by not specifying a common length but leave it as an open question for future studies. “More studies are needed to find out the lengths of satellite time series required for detecting reliable trends in other climate variables”. (P18, p2).*

== Data continuity ==  
P17:  
- It might be worth pointing out here that data continuity into the future is essential for climate change studies. If current sensors are not replaced by new ones near the end of their lifetimes, SRS climate series will be interrupted.

***Response:*** *We agree and raised the issue in the limitation section: “Availability of more time series with adequate length will depend on the efforts to maintain the continuity of existing satellite missions”. (Page 19, p1).*

P18:  
== Perspectives ==  
- What were the reasons for your selection of topics? The title suggests completeness, and the article may leave the reader disappointed by not covering important aspects of SRS. I certainly agree that ecosystem productivity is not of direct interest to climate studies in a narrow sense. Precipitation and atmospheric composition however to me seem vital components of an article such as yours, even if covered only briefly.

***Response:*** *We explained the reasons for selecting topics in this review. We also included precipitation to reflect their significance.*

P19:  
- "...making more data products available to the public" - How does this contribute to making "satellite observations more suitable for climate change studies"?

***Response:*** *The increased availability of SRS data will make them more accessible by climate scientists and lead to wider adoption of SRS data in climate change studies. More uses in turn mean more feedbacks that can lead to the improvement of the SRS observation. However, in the revised manuscript we removed this sentence to make the discussion more focused.*

P20:  
- What is meant by "dedicated satellite missions"? What are the requirements?

***Response:*** *We removed this term and move the discussion to page 19, p2. Normally the newly launched and to-be-launched satellite missions that provide measurements of a specific climate variables are called dedicated satellite missions, e.g., CO2 satellites.*

- "... implemented in other REGIONS" (ESA not representing a country but a region)

***Response:*** *The entire sentence was removed. (Page 19, p2)*

Fig 1:

- I found it somewhat confusing to encounter non-satellite remote sensing systems in this figure. Consider removing.

***Response:*** *We meant to give an entire picture of remote sensing observation of the climate system here. The figure emphasizes the global coverage of satellite remote sensing compared to other non-satellite remote sensing systems. We made this point clear in the figure caption. So we want to keep these elements of the figure.*

- All labels refer to spheres, with the exceptions of "aerosol" and "sea ice". Please remove the latter two or make them distinctly different from the other labels.

***Response:*** *We have changed the color and fonts of the two words to make them different from other labels.*

Fig 2:  
- Since you talk about trends here, why not show them in the plots?

***Response:*** *The trend lines and the values of the trends were added to the figure.*

- What does "UW" stand for?

***Response:*** *“UW” stands for the data set produced by Fu et al. (2004) from University of Washington. We decided to remove this data set from the figure since our main point is to show the conciliation of differences by RSS and UAH groups.*

Fig 3:  
- Since you are considering differences, why not show a difference image?

***Response:*** *Thanks for the suggestion. We now included a new graph to show the differences between the two data sets.*

- Visual comparison of the two plots reveals little differences. Spatial resolution appears higher in the lower one, but general spatial patterns appear to agree.

***Response:*** *The difference was now shown in the new graph (c). The spatial patterns of the two data sets agree well with each other but the magnitudes are very different.*

TECHNICAL REMARKS  
P2: "We point out what IMPROVEMENTS are needed in..."

***Response:*** *modified as suggested. (Page 2)*

P3: wording: application of something cannot "increase"

***Response:*** *Changed to “SRS has gradually become a leading research method in climate change studies” (Page 3, p1)*

P3: On THE application side, SRS...

***Response:*** *Removed ”On the application side”. (Page 3, p2)*

P3: ... cope with the IMPACT OF CLIMATE CHANGE.

***Response:*** *modified as suggested. (Page 3, p2)*

P4: Therefore the use of satellite observations in climate change studies requires a clear identification of their limitations.

***Response:*** *modified as suggested. (Page 4, p1)*

P4: In this article we review the contributions of SRS to our understanding of climate change and the processes involved.

***Response:*** *modified as suggested. (Page 4, p2)*

P8, para 1: "has not PASSED A tipping..."

***Response:*** *modified as suggested. (Page 8, p1)*

P9: I suggest not introducing an acronym for low-elevation coastal zones.

***Response:*** *The acronym was removed and the sentence shortened: “Sea level is closely related to climate because the main factors that cause sea level changes are driven by climate change and variability”. (Page 10, p1)*

P9: "mid-nineteenTH"

***Response:*** *The entire sentence was removed for clarity. (Page 10, p1)*

P11: "accurage estimates of global SLR are still MISSING"

***Response:*** *“elusive” replaced with “challenging” (Page 11, p2)*

P12: "four to six times LARGER"

***Response:*** *“more” was replaced with “larger”(Page 12, p2)*

P12: "compensated by an increase"

***Response:*** *modified as suggested. (Page 12, p2)*

P12: "under-correction"

***Response:*** *modified as suggested. (Page 12, p2)*

P16: "trend PHENOMENA and they indicated..."

***Response:*** *modified as suggested. (Page 19, p2)*

P20: "records aimed AT public use from..."

***Response:*** *The paragraph was rewritten and the sentence was removed.*

Table 1:  
- label: "URLs"

***Response:*** *The missing “s” is added.*

Fig 2:  
- "LS", "MT", "LT" not needed in line labels (information contained in sub-plot labels already)

***Response:*** *They were removed from the figure.*

Supp. Table 2:  
- AOD intercoMparison

***Response:*** *modified as suggested.*

***Reviewer #2 (Remarks to the Author):***

Overall Evaluation: Excellent and Exciting Recommended Action: Publish with Major Revisions

The authors undertook quite a commendable job and considerable effort to have a comprehensive review on the use of satellite remote sensing measurements for long-term observation of climate variables towards quantifying present-day climate change. Most of the surveys have been concentrated on passive remote sensing satellite observations (radiometers) which are in sun-synchronous orbits, potentially could incur “trend biases” due to fact that solar variations would be seen as a constant. In addition, a number of geodetic satellite observations have been includes with a substantial disproportion, favoring the passive remote sensing satellite observations. They include radar and laser altimeters, observing sea-level, sea-ice and ice-elevation changes, and spaceborne gravimetry sensor, GRACE, measuring mass changes of the Earth. My opinion is that such kind of publication is timely, cross-disciplinary, and fairly appealing to the scientific community and the public, as such, it should deserve to be considered publishable. I recommend a minor to major revision and that the authors should consider the following comments.

Major Comments

– It is quite a general critique that the paper is quite uneven in terms of various presentations of sensors and particular climate variables. In particular, the narrative on Water Vapour needs rework, some aspects of the current write-up could be misleading. Increased water vapour process positive and negative feedbacks, corresponding to more greenhouse warming and higher albedo or more clouds, respectively. The net influence of the feedback varies substantially over regions, seasons, and with interannual or longer variations. It is suggested that the authors elaborate to the extent that there would not any misleading information.

***Response:*** *We modified the water vapor section significantly to address the reviewer’s comments. We pointed out that the tropospheric water vapor content was related to surface temperature. We also listed citations that mention regional, seasonal, inter-annual variations of water vapor. The analysis show that the overall effect of the feedback from the tropospheric water vapour is positive. (Page 16, p1)*

– It is confusing that the sea-level rise assessment primarily used altimeter observations which is only 2 decades in data span (Fig. 3), while the citation used to highlight the data span required to accurately determine sea-level rise used tide gauges (not satellite measurements). While this is not a sea-level error budget paper, however, short data span of satellite data, land motion, sparseness of tide gauges, radiometer (water vapour measurement drift), instrument bias drift, etc, could all constitute errors in the sea-level measurement.

***Response:*** *The 60 years suggested by the citation (Douglas, 1997) is for removing the effect of low-frequency oceanographic sea level change. Since it is an internal variation of the oceans, it will apply to both satellite observations and tide gauges observations. The limitations of SRS observation of sea level change are general problems of SRS and have been discussed in the limitation section. (Page 18, p2)*

– Similarly, GRACE measurements only have a less than 10-year record, and ICESat observations could not sample seasonal variations of the ice sheets (sea- ice). They should been at least discussed.

***Response:*** *The impact of the shortness of GRACE measurements was discussed by Horwath et al., 2012 very well and their works was cited in the manuscript. (Page 8, p2). ICESat observation was not discussed in this article as we are focusing more on trend detections and general problems of SRS.*

– Comments on various instrument drifts and how they would be or should be calibrated?

***Response:*** *Short discussions on instrument drifts were added (Page20, p1).*

Minor Comments

– Abstract. What are orbital drifts? I don’t think orbital drifts would directly affect measurement accuracy or cause biases in the time series. As mentioned before, sun-synchronous orbital platforms are probably likely to incur trend biases.

***Response: “****Orbital drifts” were removed from the abstract. The influence of orbital drifts on the uncertainty of the time series was discussed in the limitation section (Page20, p1).*

– Introduction. Satellite remote sensing (SRS), apparently it includes geodetic satellites, but they are obviously different. It is suggested that the authors provide a definition.

***Response:*** *A definition of satellite remote sensing was added at the beginning of the introduction (Page 3, p1).*

– P.2, “On the application side, SRS…”

***Response:*** *The phrase was removed. Now the sentence was revised as “SRS is also widely used for developing prevention, mitigation and adaptation measures to cope with the impact of climate change.”*

*(Page 3, p2)*

– P.3, “continuous and stable”, it should be “calibrated/validated, consistent, and with adequate temporally and spatially sampled observations.”

***Response:*** *modified as suggested. (Page 4, p1)*

– P.3, delete “continual” (monitoring).

***Response:*** *The entire paragraph was revised. The current sentence is”* *Conventional land based observations are typically collected at fixed intervals with limited spatial coverage whereas SRS allows for continual monitoring on a global scale”. (Page 4, p3)*

– P.6, bottom. Melting of snow and ice cover is (delete “has”) important because (delete “consequences as”).

***Response:*** *Revised accordingly. (Page 7, p2)*

– P.7, ..surface, and because it contributes (delete “and contributing”) to sea level rise.

***Response:*** *Revised accordingly. (Page 7, p2)*

– P.7, Snow cover extent (SCE) over the … (delete “Snow cover extent (SCE) is probabluy the best-studied ECV based on SRS.”).

***Response:*** *The sentence was removed. (Page 7, p1)*

– P.9, population(s)

***Response:*** *The sentence was removed. (Page 10, p1)*

– P.9, five million fall partly or entirely (delete “entirely or partly”) in LECZ.

***Response:*** *The entire sentence was removed to keep the paragraph concise. (Page 10, p1)*

– P.17, The Topx/Poseidon satellite radar altimeter mission and its successors,…

***Response:*** *The sentence was changed to “. Satellite altimetry observations beginning with the TOPEX/Poseidon satellite mission indicate…”. (Page 10, p1)*

***Reviewer #3 (Remarks to the Author):***Summary:  
This paper presents an overview of various remote sensing techniques and data for climate change studies. It discusses how technology and methods have improved over time as well as remaining challenges and limitations in the various techniques. It covers a broad range of remote sensing climate products addressing many aspects of global warming.  
  
General Comment:  
This paper presents a broad, high-level overview of various remote sensing techniques and data that have been developed to monitor climate change. The paper compiles a broad range of techniques, such as SST, snow and ice, sea level, solar radiation, aerosols, etc. In this sense, this paper provides a useful service to the climate community because remote sensing and other climate scientists tend to focus on specialized fields and may not be aware of issues in other fields.  
  
However, because of the broad array of applications, it covers each very superficially. While reasonable for a high-level report, it doesn't seem to fit in a peer-reviewed science journal. This is evidenced by the fact that many of the references in the article are not to original peer-reviewed science results but rather other review papers and reports (e.g., GCOS, IPCC). The paper in essence appears to be a review of reviews. Again, this may be valuable, but doesn't seem to fit in a science journal. It could be a useful report, though there have been several similar assessments (e.g., GCOS, as well as the Integrated Global Observing Strategy reports).  
  
I think there are a few ways to take this, as I see it:  
1. A non-peer reviewed report, perhaps submitted through WCRP or other organization.  
2. A more thorough and comprehensive report submitted to a review journal (e.g., Reviews of Geophysics, etc.).  
3. A very narrow and targeted paper for Nature Climate Change that focuses on a specific issue or issues regarding the impacts of limitations of satellite data (coverage, inconsistency, etc.) on understanding and prediction of climate change. This would probably need to focus on one specific (e.g., intersensor calibration) and perhaps just a few parameters.  
As the paper is currently written, I don't think it is suitable for publication in Nature Climate Change.

***Response:*** *We agree with the reviewer that this manuscript is not a comprehensive review of the role of SRS in climate change studies. In fact, whether to produce a comprehensive discipline-specific review or to give a balanced evaluation of the contribution of SRS to climate change studies is a question we had from the very beginning. The initial writing of our review had 90 pages in the main text and more than 200 citations from a pool of over 700 papers. The current version is the 12th revision of the initial writing. Through the revising process, we came to a realization that there are already many excellent reviews focusing on a specific topic or a parameter. A comprehensive review across the entire field cannot do better than these specific reviews on the technical side of each individual subject. However, these narrowly-focused reviews are often published in highly discipline-specific venues. Therefore, the contribution of SRS to climate science and its limitations are not well explained to a wider climate research community. We believe that this is a gap that our review can help fill. Also, unlike the official reports from agencies like GCOS and NASA, we are not intending to provide an accounting list of the current status and needs of SRS. Instead, we focus on research questions that have been debated in climate change studies from a remote sensing perspective. We believe that Nature Climate Change is the most appropriate venue for publishing this review with its strong interdisciplinary feature and wide reach.*

*We disagree with the reviewer that this article is a “review of reviews”. Two reasons disqualified our article from that category. First, it is a common practice for reviews published by Nature and Science to cite other reviews. The number of reviews cited by us is comparable to others. Secondly, we did not copy contents from the review papers in our manuscript. They are citied to support a statement or a fact. For example, the GCOS report mentioned by the reviewer is cited to support our statement that SRS is an important tool for climate observations.*

Minor Comments:  
P3, last line: rephrase as "...cope with the impacts of climate change."

***Response:*** *modified as suggested. (Page 3, p2)*

P5, line 5: suggest "questioning" instead of "challenging"

***Response:*** *The entire sentence is revised. (Page 5, p1)*

P7, Ref. 38: there are now more updated sea ice extent trends published - Parkinson and Cavalieri, Cavalieri and Parkinson, both 2012 in The Cryosphere, volume 6.

***Response:*** *We adopted the new references since the authors significantly modified their estimates of the trend of sea ice extent. (Page 8, p1)*

P8, Ref. 43: couldn't find this reference - the full listing (incl. title) should be in the reference list

***Response:*** *We followed the reference style required by Nature Climate Change. The title of the reference is “Ice-sheet uncertainty”. The NCC style requires that title of communication or discussion papers should not be listed. In this revised paper, this citation was replaced by a new one (Shepherd et al., 2012). (Page 8, p2)*

P9, first paragraph: use consistent units for mass balance - in one it is Gt/year and the next line it is a m/year of water equivalent

***Response:*** *We cited the original numbers from the references. In order to address this comment, we converted all numbers to mm/year equivalent unit. (Page 8, p2)*

P10, line 2: "...since the end of the last century". This is a bit ambiguous - since the end of the 20th century?

***Response:*** *Modified as suggested. (Page 10, p1)*

P10, line 6: use "lowest" instead of "minimum"

***Response:*** *The sentence was revised and the use of “minimum” was avoided. “Based on sites with good-quality tide gauge records, the global mean SLR was estimated as 1.9±0.4 mm yr-1 since 1961”. (Page 10, p1)*

P10, 3rd from last line: do you mean "Argo"?

***Response:*** *Modified as suggested. (Page 11, p1)*

P13, middle: "...to but a small trend..." needs rephrasing

***Response:*** *“but” was removed to make the sentence clearer. (Page 13, p1)*

P14: "...effectively glaciate supercooled clouds..." I'm not familiar with "glaciate" in this context - perhaps another word is better?

***Response:*** *The sentence was modified into” Cloud laser data show that dust particles lifted to the cold cloud layer effectively promote the formation of ice crystals in supercooled clouds and decrease the albedo of clouds”. The term “glaciate” was avoided. (Page 15, p2)*

P15, line 1: how long is "short-term" here?

***Response:*** *Decadal scale added to explain the short-term. (Page 15, p1)*

P17, Ref. 91: This reference deals with improper use and combination of different datasets from different sensors (SSM/I and AMSR-E) and isn't really a continuity problem. First, the SSM/I sensor continued long after the launch of AMSR-E and the follow-on sensor, SSMIS, is still collecting data, so the consistent passive record is ongoing. Second, the AMSR-E algorithm can be adjusted to match SSM/I or vice-versa - this has been done for previous sensor transitions.

***Response:*** *We used the example to show the problem of continuity in a broader sense. If the improper use was not identified, the measured trend by previous sensors will not continue but was changed. In that sense, the method to combine different datasets from different sensors caused a discontinuity in trend detection. We revised the entire paragraph so the citation is no longer used (Page 18, p3).*   
  
P17, start of "Accuracy and stability": Suggest "From the dawn of earth observation from space..."

***Response:*** *The sentence was removed. (Page 19, p1)*

P18, middle: "that" instead of "which" before "...significantly affect..."

***Response:*** *Modified as suggested. (Page 21, p2)*

P19, 2nd from last line: typo "e"

***Response:*** *Removed as suggested.*

P20, middle: add "are" to "...research groups and are largely unavailable..."

***Response:*** *The entire paragraph was revised. The discussion on data availability was removed to make the article more focused. (Page 19)*

Ref. 60: Needs title in reference list  
***Response:*** *We followed the reference style required by Nature Climate Change. The title of the reference is “Reply to comment by J. L. Lean on ‘Estimated solar contribution to the global surface warming using the ACRIM TSI satellite composite’”. The NCC style requires that titles of communication or discussion papers should not be listed. The citation was replaced with a newer one (Benestad and Schmidt, 2009).*

***Reviewer #4 (Remarks to the Author):***  
First, I would like to commend the authors for their efforts to consolidate such a wide range research. This work is a sizable undertaking and certainly a valuable resource. The supplemental materials are quite practical and indeed serve as an excellent entry point.  
  
However, while this work accomplishes it's goal of highlighting SRS contributions to climate change research, some of the conclusions/perspectives are not very substantial. Also, my concern is that this paper offers few/little new insights or interpretations; only consolidates existing research. Perhaps this could be OK given the pragmatic nature of the work.

***Response:*** *The perspective section was significantly revised. We pointed out some new directions that the SRS can work on. However, there is a limitation of our understanding of the SRS. We expect that this article can stimulate others to come up with some innovative ideas on how to improve the situation.*

The "Limitations" section followed by the "Perspectives" section seem to leave SRS in a bad way. For example:  
Limitations of SRS:  
- Climate change studies need 30+ years ...  
- Lifespan of most satellites is around 5 years ...  
- Uncertainties are potentially high in combined data sets ...  
- The lack of instrument calibrations [...] is a major problem ...  
- Most satellite sensors cannot be recalibrated ...  
- Uncertainties [...] can affect the magnitude of detected trends and even change their direction ...  
  
Perspectives:  
- Deficiencies [...] must be addressed [...] to retrieve reliable trends of climate change from satellite observations ...  
- Dedicated satellite missions are needed in the long-term ...  
- Rigorous reanalysis methods should be developed to remove errors ...  
- The availability of products should be improved ...  
- Given the current global economic downturn ...  
- cancelation of the Climate Absolute Radiance and Refractivity Observatory mission ...  
- cancelation of the Deformation, Ecosystem Structure and Dynamics of Ice mission ...  
  
It is likely that the authors are attempting to motivate researchers and ignite policy makers by highlighting deficiencies and stressing the impact of cancelled SRS missions but I'm not quite sure it comes off this way.

***Response:*** *We agree with the reviewer. Although our intention is to provide a balanced evaluation of the role of SRS in climate change studies, our writing may actually make SRS look " bad”. We rewrote sections of limitation and perspectives in a more positive manner. (Page 18-24)*  
  
The water vapor section is a little sparse considering water vapor is ~ 50% of the green house gas effect. See  
G. Schmidt, R. Ruedy, R. Miller, and A. Lacis. Attribution of the present-day total greenhouse effect. Journal of Geophysical Research, 115(D20):D20106, 2010.  
Citations of Trenberth and Randel would not be amiss here. See  
K. Trenberth, J. Fasullo, and L. Smith. Trends and variability in column-integrated atmospheric water vapor. Climate Dynamics, 24(7):741-758, 2005.  
W. Randel, Variability and trends in stratospheric temperature and water vapor, Geophys. Monogr. Series, vol. 190, doi:10.1029/2009GM000870, 2010

***Response:*** *We revised the section of water vapor and precipitation to address the reviewer’s concerns. (Page 16-17). The importance of water vapor was emphasized (Schmidt et al., 2010). We discussed the major discoveries made by SRS on the variability and long-term trends of water vapor contents in troposphere and stratosphere (Trenberth et al, 2005; Shi and Bates, 2011). The possible links between various climate processes that affect the water concentration were also mentioned (Randel, 2010., Fueglistaler, 2012). We also added a new paragraph of precipitation with discussion on the regional variability and global mean trends.*

On a subjective note, at times the writing is awkward. For example  
"SRS has greatly enhanced our understanding of climate system variations and their impact by   
allowing continual monitoring at a global scale whereas conventional observations are taken   
at fixed times and locations"  
could possibly be better stated as:  
"Conventional land based observations are typically collected at fixed intervals having limited spatial coverage whereas SRS allows for continual monitoring on a global scale. This continuous global coverage has greatly enhanced our understanding of climate variations and their impact. "   
Rephrased, both sentences end on a positive SRS note. And the main point, "continuous global coverage", is reiterated to the reader.

***Response:*** *Thank the reviewer for the suggestions on writing. All suggested modifications were accepted. We also asked a professional English editor to help proof read the revised manuscript. (Page 4, p3)*

Likewise:  
"The ability of the time series of climate variables recorded by satellites to meet these requirements   
influences the reliability of identified climate change trends and our views of the quality of climate models and thus projections. Therefore adoption of satellite observations in climate change studies without accounting for their limitations is likely to lead to questionable results."  
could be perhaps be phrased as:  
"The deficiencies of SRS data could have considerable statistical effects. Such limitations should be accounted for when interpreting these data over many years for climate studies."

***Response:*** *The sentences were rewritten by adopting some of the reviewer’s suggestions (page 4, p1)*

Finally:  
"Warming of the surface and troposphere with a local maximum trend in the upper levels in the tropics due to increased anthropogenic greenhouse gases has been consistently predicted by climate models"  
might be trimmed down to something like:  
"Surface and tropospheric warming due to escalating greenhouse gases has been consistently predicted in multiple climate models."

***Response:*** *modified as suggested (page 6, p2).*