Reviewer 2:

The authors use functional data analysis approaches to detect the changes of climate conditions at local and regional level. Leaf Area Index (LAI) is utilized as a metric for climate change conditions. The data used in the study are collected in the north-western United States and south-western British Columbia, Canada.

1. The objective of this manuscript is unclear. It would be good to clarify it in the introduction. A clear objectives statement has been added to the introduction. **Line 92-94**.

2. Explain how to detect the change in vegetation dynamics. In this paper we are using the term "vegetation dynamics" to refer to intra- and inter-annual phenological shifts in vegetation as detected by satellite-derived greeness (Leaf Area Index). This has been addressed in the introduction.

3. Figures and tables are not poorly organized and referred. For instance, in Table 1, the caption is "Summary of Max LAI temporal correlation results.", but "Fig 2 and Tables 1 and 2, show calculated correlations between detected 263 annual maximum LAI at each site and time." in Line 262. All numbers in Table 1 are greater than 1.

We thank this reviewer for identifying a clear point of miscommunication from these tables. The correlation between sites is discretized, where significant positive correlations are determined to be "Greening Sites" and vice versa for negative correlations. We have added several details to both tables, and we ask the reviewer to confirm that our additions convey our presentation of our introductory correlation analysis more clearly. (Our choice to present the correlation results this way follows Berner et. al. Sept 2020 in Nature Communications.)

4. Multiple functional analysis methods are used in this paper, functional kriging, functional principal component analysis, functional canonical correlation analysis, and functional clustering (?). However, I am not clear if they are connected or independent analyses. If they are connected, explain how they can be integrated.

We agree that the flow of the methods section should be improved. The overall methodology is outlined as follows:

1) Smoothing of LAI profiles
2) Cluster these profiles using the proposed functional cluster analysis model.
3) Spatial prediction/alignment of climate variables to match the LAI CDR.
4) Regionally averaging of profiles by Cluster
5) fPCA and fCCA of regional average profiles by Cluster.

We have made several modifications to the methods section to improve the flow, and we have also included a flow-chart the describes the full modeling process (labeled now as Figure 3 in the document), and how the methods are integrated together to accomplish the results found in this work. We hope that these changes are satisfactory to the reviewer.

5. There are several problems with using acronyms over full words. Examples: NDVI (Line 60) , AVHRR (line 105, explained in line 126), and ERA (Line 113). These acronyms have been appropriately explained and only used after explanation.

6. B-spline basis function is used to express the raw data as a smoothed function. Explain more details about the expansion, such as knots, order, and K (the number of basis functions).
We have added these details in the paragraph after equation 5 in the Smoothing LAI section.

7. Line 130: Explain why the daily LAI measurements are aggregated to weekly average. Any problem for using the daily measurement?

We have added this explanation as an additional sentence in Section 2.2:
We chose to take weekly averages because of the regular occurrence of missing values at daily resolution and this is justified by the stability of vegetative processes from day to day. **Line 125-127**

8. Line 185: I do not understand why the smoothed curve is considered as a vector again after converting a vector of measurement discretely measured to a smoothed function. A correlation for functional data could be used in place of the pairwise correlation used.

We appreciate the reviewers' clarifying question here as it marks a weakness in the way this is presented to a diverse remote sensing audience. A “smooth function” in a theoretical sense has an infinite number of values on its continuously defined domain. However, any computations or representation of the smooth functions must be done using a refined, but discretely recorded time-mesh. The time mesh is easily generated/altered since it is derived using the basis function coefficients of the selected spline model. In our work the original LAI data is measured weekly, when representing the “smoothed” LAI curves, they are plotted using a time-mesh that is double the resolution (2x the number of time points) which means that the correlation plots have 2304 dots (1152x2). The choice of the time mesh arbitrary since it can be refined to the desire of the user, but there is a balance between having too rough of a time grid (which fails to depict the smoothness of the spline model) and too fine (which makes computations for higher dimensional data problems more taxing).

We have added some brief commentary to this paragraph. We encourage the reviewer to examine the additions, and inform us if they feel that more clarification is needed.

I also wonder whether computing the correlation appropriately measures ”the strength of monotonicity of the ellipsoidal relationship of coordinates”.

This is an excellent question that should be addressed as well, and the choice used in this work comes down to computational efficiency and normalization. There are different dissimilarity measures that can be implemented to measure the similarity of curves such as L^P-norm methods (integral of the difference between two functions) and dynamic time-warping. However, rank correlations are quickly computed and capable of detecting nonlinear monotonic relationships. Since the almost all sites undergo very similar greening processes every year, it is clear that the plotting one sites LAI with respect to another will be represented by a “line-drill (aka gym-suicides)” motion. This movement is ellipsoidal but “skinnier ellipsoids” will have

higher spearman correlations and “wider ellipsoids” will have lower spearman correlation. Using this measure of dissimilarity in our clustering model successfully separates sites with a double peak in LAI from sites with a single peak in LAI. It also shows evidence of separating curves by the timing a magnitude.

Ultimately, this may be captured as well or even better with more advanced dissimilarity metrics, but we rely on the philosophy of using the simplest/fastest tools first for big data problems since they will be the tools that will extend most efficiently to big data problems. In this work we determined that exploring a wide variety of dissimilarity metrics for our functional clustering model should be left to future work. **We have added two citations of works that propose other tools for measure dissimilarity between pairs of functions including Localized Mutual Information and Dynamic Time warping.**

They are 2 sentences added to the end of this section to elaborate further on some of these details. Lines 225-226.

9. Line 264: Explain how the significant correlations are determined. by a statistical testing? Why is $\alpha = 0.15$ considered?

This is mentioned in Table 1’s and 2’s new caption. We encourage the reviewer to inform us if this does not address this question to their satisfaction.

10. Line 281: Is it a functional cluster analysis? How to determine k? 1

We have added explanation of our choice of k=5 in paragraph 3 of the results section. **Line 326-330**

Minor Comments:

1. Numbering sections starting from 0. The sections have been re-numbered to start at 1.

2. Line 88: Explain ”different information”. This says “differential information” **Line 78**

3. Line 136: ”it is clear that”? We have changed this sentence to say “we found that” instead of “it is clear that” to better convey the purpose of that sentence. **Line 130-131**

4. Line 93-102: It seems to be better to move this paragraph to smaller variances compared with... This paragraph has been moved into a sub-section of the Methods section (2.1 Study Region). Seems like there is a typo in this comment, I am not sure what the “smaller variances compared with... “ is referring to.

5. Line 103-112: conclusion? We have made major revisions to our introduction and conclusions sections, we are unclear on what issue this comment was referring to but we welcome further details if needed.

6. Line 169: Clearly define the following notations: 1) Is Y a matrix?, 2) Is $-\rightarrow y$ i a vector? what does the subscript i represent?

This is clarified with an addition to this sentence explaining that it is a vector which is discretely measuring/representing a continuous process.

7. Line 174: optimal λ? This correction has been made to say optimal λ. **Line 172**

8. Line 181: Address that B-spline is used as basis function. In addition, specify the corresponding tuning parameters, such as degree (or order), the number of knots, and the locations of the knots.

We have addressed these comments in an earlier comment from this reviewer.

9. Figure 1: In the caption, 1) ”B-spline smoothed LAI splines”? and 2) explain why the two spearman correlations, 0.988 and 0.769, are different.
We have added another sentence explaining why the correlation is higher in the left image than the right image. We have also clarified the 1 fragment sentence of the caption.

10. Line 210: Functional kriging? The title of this section has been changed to “Ordinary Functional Kriging”. **Line 231**

11. The title of Section 1.7 seems to be not reasonable. Functional principal component analysis?

This section is now labeled as Section 2.9. It is a section that explains how we intend to monitor interannual variation in regional LAI which includes the use of functional PCA. The title “Interannual Regional LAI and Climate Variation Monitoring” seems to be justified to us. Can the reviewer clarify their concerns with this title?