Referee #1

We thank Referee 1 for her or his review of our manuscript. Below, we address the comments by Referee 1 black with our reply in blue. We numbered the comments of referee 1.

This manuscript uses Solar-Induced Fluorescence (SIF) data to investigate the impact of changes in vegetation and carbon uptake, due to fire and forest loss/gain. The study specifically focuses on two selected regions in Australia and China. The analysis in Australia, examining the impact of fires, utilizes TROPOMI SIF data, while the analysis in China, assessing the effects of afforestation and climate change, utilizes GOME-2A SIF data.

1. Additionally, the study establishes an empirical relationship between satellite SIF and Gross Primary Productivity (GPP) for a single site and extrapolates this relationship to estimate GPP and changes in GPP over broader areas of satellite SIF data. It is important to note that this approach assumes a constant SIF-to-GPP conversion ratio across all study areas, which may not hold in reality.
To estimate how GPP changed after a massive fire in the Australian Nunnett-Timbarra region, we require an empirical relationship between SIF and GPP that is sufficiently representative for our Nunnett-Timbarra study area. By comparing TROPOMI SIF data with eddy-covariance GPP data over the nearby Tumbarumba flux tower site, which has similar biogeography as our Nunnett-Timbarra study area, we have obtained such a SIF-GPP relationship. In the original manuscript we tested its representativeness by comparing the SIF-GPP relationship over Tumbarumba vs. that over Nunnett-Timbarra (derived from collocated TROPOMI SIF and FluxSat GPP data), and find very similar values, which lends credence to our assumption that the TROPOMI SIF-GPP_{ec} relationship can be used.

Perhaps the reviewer has misunderstood that the SIF-to-GPP relationship obtained over Tumbarumba is not applied across all study areas, but only to the Nunnett-Timbarra case study, after verifying that Tumbarumba and Nunnett-Timbarra indeed have similar SIF-to-GPP ratios. Modifications in the abstract are made to make it clearer that the empirical SIF-GPP relationship, obtained over Tumbarumba (Australia), is solely applied to the Nunett-Timbarra area and that it is representative to the case study area, see lines 11 and 12 of the revised manuscript with tracked changes.

The uncertainties in the SIF-to-GPP relationship due to footprint differences, spatial translation, and pre- and post-fire applicability are now discussed in detail in supplement S2.1 and in the main text in lines 238—239, and lines 257—262 of the revised manuscript with tracked changes.

2. While the authors consider two GPP datasets (OZflux GPP and FluxSat GPP) and provide a range of GPP uncertainty, it is possible that actual uncertainties extend beyond the provided range.
We acknowledge the referee's concerns regarding the uncertainties in our estimates of how GPP changes following the fire. We therefore extended our examination of the uncertainties associated with the estimation of SIF-based ΔGPP, both using SIF-GPP relationships based on FluxSat and based on OzFlux GPP. We addressed the uncertainty in ΔGPP via uncertainty propagation following Eq. (1) in the original manuscript, and furthermore considering uncertainties in assumptions regarding (1) the representatives of the relation between SIF—GPP over Tumbarumba for the Nunnett-Timbarra study-area and (2) the applicability of SIF—GPP relationship obtained in the unburned period and area to the post-fire period and area, and (3) footprint differences in the SIF and GPP estimates.

Regarding the latter, additional analysis shows that differences in footprint size of the Tumbarumba eddy covariance tower and the satellite pixel size or FluxSat grid cell size do not introduce any further uncertainties that matter. Retrievals of MODIS NDVI in a vicinity of 1 km (eddy covariance footprint) or in a vicinity of 9 km (TROPOMI or FluxSat footprint) show a very similar distribution of values. Thus, differences in footprint between flux tower and satellite do not contribute substantially to uncertainties in the final estimate.

However, the uncertainty-estimate in ΔGPP following from best estimates of individual uncertainty contributions, is driven by the relative uncertainty in the detection of changes in TROPOMI SIF (30%), the uncertainty from the *calculation* of the SIF-GPP relationship (10-15%), and especially in the representativeness of the SIF-GPP relationship from the unburned period for the post-fire period (50-60%). Adding these terms in quadrature, we estimate that our estimates of ΔGPP are associated with a relative uncertainty of 60%.

The uncertainty propagation estimates are included in supplement S2.1.

3. In the China study, the linear regression between SIF and climatic data appears to be somewhat superficial, and it is crucial to recognize that this relationship may vary depending on specific geographical locations.
Obviously, the proposed relationship between SIF and climatic data over China is specific for the selected geographic location and period (here summertime), as mentioned in lines 319—320 of the original manuscript. We modified the manuscript to emphasize that the relationship is strictly local, see lines 339 of the revised manuscript with tracked changes.

4. In general, the results appear reasonable; however, the uncertainty range is still too large.
We also think that our results appear reasonable, and we could have done more in the original manuscript to assess a realistic uncertainty range. After the revision, we do so as discussed above in response to the referee's point 2, by including a formal uncertainty propagation (accounting for uncertainties in satellite SIF retrievals, in GPP-estimates from eddy flux towers, and in the representativeness for SIF-GPP relationships before and after the fire). This uncertainty analysis is included in supplement S2.1.

5. This study also does not sufficiently prove the credibility and accuracy of using SIF data to assess changes in Gross Primary Productivity (GPP) or carbon storage in response to vegetation disturbances. In short, I did not see the novelty of this study.
Our study assesses the feasibility to monitor the impact of land use changes on GPP via satellite-based SIF. In particular, the Nunnett-Timbarra-case study shows how SIF can be used to quantify changes in GPP. Both burned area, reports from eyewitnesses on the ground, as well as TROPOMI SIF show that following the fires, a sharp reduction in carbon uptake was followed by relatively rapid regrowth of vegetation. Hints for rapid regrowth after fires have been reported for Australian forests by others (e.g. Gibson and Hislop, 2022), which provides some support for our method and findings. The massive reforestation occurring in our China case-study, reported from Chinese yearbooks, and observed from space, strongly suggests an increase in GPP, which is captured by increases in satellite-SIF. Our work points the way ahead on how satellite-based SIF can be used in the future to assess changes in GPP from land use change, namely by (a) application of ecosystem-specific (local) SIF-GPP relationships, and (b) accounting for co-occurring dynamics in factors that affect GPP, including fluctuations in soil moisture and temperature. Regarding the referee's remark about the accuracy of using SIF, we refer to our response under point 2. An extensive validation could help to confirm the accuracy of our method. Such a program requires ground-based measurements of GPP or carbon storage taken in regions with ongoing vegetation disturbance. Such measurements were not available to us when we started this study.

Detailed comments:
6. The title of the study appears overly broad. This research specifically focuses on the analysis of vegetation carbon dynamics using SIF data in selected regions of Australia and China.
We agree that the original title may appear too broad. Therefore, we modified the title of the revised manuscript to: "Monitoring the impact of forest changes on carbon uptake with solar-induced fluorescence measurements from GOME-2A and TROPOMI for an Australian and Chinese case study".

7. L75 and L100: The use of "daily proxies" may be an overly optimistic characterization of satellite data. It would be helpful to provide information on how frequently TROPOMI and GOME-2A revisit the same location. Additionally, it is worth exploring whether cloud cover significantly limits data availability, particularly in tropical regions.

The term "near-daily", not "daily", in line 73 of the original manuscript refers to the near-daily global coverage of the instruments TROPOMI and GOME-2A, from which SIF can be retrieved. GOME-2A covers the globe in 1.5 days (Munro et al., 2016) and achieves daily coverage beyond 40° latitude. We made changes in section 2.1, specifically lines 73—75 in the revised manuscript with tracked changes, to make it clearer that the term "near-daily" refers to the coverage of the mentioned instruments and not per se to the SIF observations.

SIF data availability is indeed impacted by cloud cover. Meaningful SIF is retrieved under clear sky conditions. A sentence explicitly stating the filtering of SIF based on clear-sky conditions is added to the revised manuscript, lines 85—86 in revised manuscript with tracked changes.

8. 152-154: It would be beneficial to clarify the purpose and specific objectives of the global regression model.
The referee is presumably referring to the FluxSat product. We now clarified the specific objectives of the FluxSat GPP product from Joiner et al. (2018) in line 150 of the revised manuscript with tracked changes.

9. Additionally, there is some confusion regarding which GOME-2A SIF dataset is being referenced, as there are two GOME-2A SIF products.
The FluxSat GPP model utilizes the GOME-2A SIF (v27) dataset by Joiner et al. (2013), as mentioned in line 150 of the original manuscript. This differs from the SIF product used in our analysis of the China case study. In our analysis the GOME-2A SIFTER v2 product is used, as mentioned in line 103 of the original manuscript. In the revised manuscript, we clarified the use of the GOME-2A SIFTER v2 product for the China analyses in the figure titles of Figures 5 and 6 of the revised manuscript.

10. L215: Two assumptions are implicit in this statement. First, it assumes that the SIF-GPP relationship observed in Tumbarumba is representative of the entire study area.
The SIF—GPP relationship in Tumbarumba holds (to first order) over the studied area. This is supported by the following:

1. Similar biogeography of lowland Eucalypt Forest in both areas, as discussed in line 217 and shown in Figure 1b of the original manuscript.
2. Very strong correlation between TROPOMI SIF over the Tumbarumba and TROPOMI SIF over the Nunnett-Timbarra case study region (r=0.92), as discussed in line 218 and shown in Figure A1b (now Figure S2.4b) of the original manuscript.
3. Very strong correlation between FluxSat GPP over the Tumbarumba and FluxSat GPP over the Nunnett-Timbarra case study region (r=0.79), as discussed in line 219 and shown in Figure A1c (now Figure S2.4c) of the original manuscript.

All this suggests that the SIF-GPP relationship at Tumbarumba is reasonably valid over the study area, *until this burned down*.

In the revised manuscript, modifications are made to explain the validity of the assumption in a clearer way, lines 220—225 of the revised manuscript with tracked changes. Furthermore, we now obtained SIF—$GPP_{FluxSat}$ relationships over (i) the Tumbarumba site, and (ii) the Nunnett-Timbarra area to test the validity and uncertainty of the assumption. In the revised version we included the uncertainty analysis in supplement S2.1, specifically in lines 56—59 of the supplement. The new analysis indicated a difference on the order of 4% between the SIF—GPP relationship over both areas, this is stated in lines 225—226 of the revised manuscript with tracked changes.

11. If this assumption holds, the second question arises: whether the SIF-GPP relationship remains consistent both before and after a fire event. It's important to note that the factor of 2 difference between the SIF-OzFlux and SIF-FluxSat methods highlights a significant level of uncertainty.
The rounded factor of 1.6 difference between the SIF—OzFlux and SIF—FluxSat relationship can indeed not be ignored. Despite this, strong correlation exists between TROPOMI SIF and OzFlux GPP (r=0.91) and between TROPOMI SIF and FluxSat GPP (r=0.94), indicating consistent dynamics. Our findings align with Joiner et al. (2018), where good correspondence between FluxSat GPP and

independent FLUXNET 2015 GPP data was found but with a magnitude difference up to a factor of 2 over some sites. Modifications are made in the revised manuscript to enhance clarity and to discuss this uncertainty in more depth, see lines 231—239 of the revised manuscript with tracked changes.

The question regarding the SIF—GPP consistency post-fire is valid. Our examination of SIF—GPP using FluxSat GPP over the Nunnett-Timbarra area before and after the fire, showed a 14% lower post-fire value for the SIF-GPP slope, as discussed in line 245 of the original manuscript. This indicates consistency between the found SIF—GPP relationship for pre-fire and post-fire conditions. Our uncertainty propagation analysis, included in S2.1, showed a substantial uncertainty of 50% in the slope of SIF—GPP over the post-fire conditions. This uncertainty is higher than in the slope of SIF—GPP over pre-fire conditions. We acknowledge this uncertainty, assuming it extend to the application of the SIF—GPP (computed over Tumbarumba) to post-fire conditions. Therefore, this conservative 50 % uncertainty is adopted in the uncertainty of the application of the SIF—GPP relationship to post-fire conditions.

12. There's also some confusion surrounding the use of the Nunnett-Timbarra River area to test the second question, specifically with the SIF-FluxSat method. It would be beneficial to demonstrate the changes in the SIF-GPP ratio across the entire study area for clarity (instead of just over one pixel).
The SIF—$\text{GPP}_{\text{FluxSat}}$ relationship over the Tumbarumba site is *not* computed over just one pixel. We acknowledge that our explanation regarding the computation (caption of Table A1 of the original manuscript) may be confusing. In the revised manuscript we enhanced the clarity of the selection method by moving it from the caption in the table (Table S2.1. in the new supplement) to the text in supplement S2 (formerly appendix A in the original manuscript), specifically in lines 31—34 of the new supplement.

In our analysis of SIF-based GPP, the SIF—$\text{GPP}_{\text{FluxSat}}$ relationship over Tumbarumba is used to align with the method in which SIF—GPP_{ec} (with ec referring to the eddy-covariance flux tower) is used. The discrepancy between the relationship over Tumbarumba versus the Nunnett-Timbarra River area is small and on the order of 4%. As mentioned in the response to point 10, this is now discussed in supplement S2.1 and in lines 225—226 of the revised manuscript with tracked changes.

13. L285: It might be a chicken and egg question because increase of vegetation may benefit soil conditions (like soil moisture). You can't conclude which causes which based on the analysis in the manuscript.
It is indeed not possible to disentangle the impact of changes in soil moisture and forest cover on vegetation activity, as already discussed in lines 332—335 of the original manuscript. Our analysis in section 4.2 of the manuscript accounts for this intricate relation by considering the simultaneous impact of both factors on the vegetation dynamics. Nevertheless, from our results we can conclude that the increase in vegetation, likely in tandem with increasing soil moisture, had a positive impact on vegetation activity. Section 4.2 is modified to clarify these conclusions, see lines 352—353 of the revised manuscript with tracked changes.

14. L305: Can the authors remind me what's the meaning of S(t), T(t), and A(t). (PS: I learned it from Table 1 later).
The meaning of S, T, and A is introduced in lines 295—297. S(t) represents the soil moisture (in %) over year t, $T(t)$ the maximum temperature (in °C) over year t, and A(t) the total forest coverage (in km^2) over year t. To ensure clarity, the meaning of S(t), T(t) and A(t) is repeated right after the introduction of equation 3, lines 326—327 of the revised manuscript with tracked changes.

15. The model can be used to model SIF, but why bother to model SIF? Why not directly model leaf area index, or carbon storage, or GPP, NPP, NEE, something that are more related to vegetation health and carbon status?
Carbon storage or carbon fluxes like GPP, NPP or NEE are more directly related to the carbon status than SIF. However, this study aims to assess the feasibility of SIF to monitor the impact of changes in land use change (e.g. reforestation). The mentioned carbon fluxes can't be directly retrieved from

satellite observations but need to be inferred. SIF on the other hand is closely related to ongoing carbon storage via photosynthesis, which makes it -in principle- an attractive monitoring tool.

The model was used as an approach to enhance the understanding of the impact of the drivers on observed SIF variations, rather than the modelling of SIF itself. We modified section 4.2 to make our approach and its goal clearer, see lines 314—315 of the revised manuscript with tracked changes.

References

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Referee #2

We thank the Referee 2 for this review of our manuscript. Below, we address the comments with the comments of Referee 2 in black and our reply in blue.

Review of "Monitoring the regional impact of forest loss and gain on carbon uptake with solar-induced fluorescence measurements from the GOME-2A and TROPOMI sensors"

The manuscript presents SIF as a promising tool for monitoring regional land-use changes with two case studies, very different from one another, one in Australia and another in China. The study highlights that although there are uncertainties, SIF was able to monitor changes in vegetation dynamics linked with sudden changes due to wildfire (in Australia) as well gradual increase/decrease due to afforestation and deforestation (in China). Using semi-empirical relationship, the manuscript also quantified absolute change in GPP for Australian case study.

I enjoyed reading the manuscript. The method was clear and well integrated with the main text. The text and figures were largely clear and well communicated (although I have some suggestions). One of the major assumption in the manuscript regarding the SIF-GPP relationship before and after fire and in reference and burned area was well justified, even though the uncertainty is large (which is always trickly when comparing satellite and flux site data as flux site GPP is quite uncertain in itself). Overall, I would suggest a minor revision with few suggestions (given below).
We thank Referee 2 for these comments.

Figure 1a – The month of burn is unclear and comparing this with Figure 2a, it seems that the forest burning occurred in January and February 2019. So I would suggest to modify the legend of Figure 1a.
We agree that the legend of Figure 1a should be modified. We revised the legend of Figure 1a, such that the contrast in color is higher. Specifically, January and February 2019 (the two months of burning), have a blue tone, while the other two months of the fire season, November and December 2018, are denoted in brown colors.

I would reorder Appendix A and B, since in the manuscript Appendix B is referred before Appendix A. Appendix B is indeed referred first (in line 123 of the original manuscript) and discusses the trend correction in GOME-2A SIF data prior to the analysis. Therefore, we reordered Appendix A and B in the revised manuscript, of which the information is now place in supplement S1 and S2. The content of Appendix A of the original manuscript is now presented in supplement S2 and the content of Appendix B of the original manuscript in S1.

Lines 234-249: I would suggest using the abbreviations used in Figure A3 here, as its presently difficult to understand when you compare the numbers.
We agree that introducing (after line 233 of the original manuscript) and using the abbreviations that refer to the two SIF-based and GPP-based reductions in GPP, namely $\Delta GPP_{SIF,ec}$, $\Delta GPP_{SIF,FluxSat}$ and $\Delta GPP_{FluxSat}$ increase the readability.

In the revised manuscript, the same abbreviations for SIF-based GPP and FluxSat GPP as used in Figure S2.6 (formerly Fig. A3 in the original manuscript) are used in section 3.2. Furthermore, we implemented these abbreviations ($\Delta GPP_{SIF,ec}$, $\Delta GPP_{SIF,FluxSat}$ and $\Delta GPP_{FluxSat}$) throughout section 3.2 in the revised manuscript to enhance the consistency and clarity.

For e.g., in line 242 it is not clear to me what is FluxSat GPP compared to, because the first part of the sentence also refers to FluxSat GPP.
We agree that the sentence in line 242 is unclear and should be modified. The sentence in line 242 reads: "*For comparison, FluxSat GPP provides a fire-induced loss of 133 GgC over the monitored period, a reduction of 58% compared to FluxSat GPP in February—November 2018*". This sentence discusses two findings:

- The *fire-induced loss of 133 GgC* refers to the difference in total GPP at the burned area with respect to GPP at the reference area over February—November 2019 (shown in Figure 4b).
- The total GPP at the burned area over the February—November period is *58%* less in 2019 (post-fire) than in 2018 (pre-fire conditions).

In the revised manuscript, we broke the sentence into two separate sentences to enhance the understanding, see lines 253—256 of the revised manuscript with tracked changes.

There are a few instances in the manuscript where the main text is largely similar to the Figure caption, for e.g., Lines 257-262 similar to Figure 5 caption. Please consider modifying it
We agree. In the revised manuscript, redundancy is reduced in several sections where the main text was similar to the caption of the described figure. See line 170, lines 188—189, line 245, and lines 275—279 of the revised manuscript with tracked changed.

Lines 280-294: Please add some figures in the supplementary to highlight this temporal variability of climatic variables.
We now included Figure S3.7 in supplement S3, showing the temporal variability of (a) maximum temperature and (b) soil moisture over the 50 selected (reforested and deforested) cells in the Northern China case study. The figure is now referenced in line 304 and 305 of the revised manuscript with tracked changes.

Section 4.2 Have the authors tried to include the incoming solar radiation as a factor in this model, as radiation is an extremely important variable for GPP?
Indeed, incoming solar radiation is a factor of importance in driving vegetation activity. Especially diffuse light is known to enhance the light use efficiency of vegetation and positively impact GPP (e.g. Xin et al. 2016). The impact of diffuse light is also captured using SIF, where a stronger correlation between tower-based SIF and light use efficiency was found than under direct light conditions (Yang et al., 2015). However, the GOME-2A SIF observations used here are all taken under (mostly) clear-sky conditions, when direct radiation and temperature are generally well-correlated (e.g. Aubinet, 1994).

Therefore, we do not expect a stronger fit of the model with an addition of (or replacement of maximum temperature by) incoming solar radiation.

The original manuscript did not discuss the clear sky-bias of satellite SIF measurement. In the revised manuscript, we now mention the cloud filtering in section 2.1 in lines 85—86 of the revised manuscript with tracked changes. Additionally, the (mostly) clear sky-bias of SIF is now briefly discussed in supplement S2 (formerly appendix A).

References

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Yang, X., Tang, J., Mustard, J. F., Lee, J. E., Rossini, M., Joiner, J., ... & Richardson, A. D. (2015). Solar-induced chlorophyll fluorescence that correlates with canopy photosynthesis on diurnal and seasonal scales in a temperate deciduous forest. Geophysical Research Letters, 42(8), 2977-2987.

Dear editor,

In examining the spatial representation of the selected FluxSat GPP grid cells over the Nunnett-Timbarra river area, we identified a mistake in the selection process. The initially selected cells covered a larger region than intended, impacting the estimated loss in GPP using FluxSat ($\Delta GPP_{FluxSat}$). In our study, $\Delta GPP_{FluxSat}$ is used for evaluation of the SIF-based GPP loss estimates.

After refining the selection to align more precisely with the Nunnett-Timbarra river area, we obtained a revised estimated loss FluxSat GPP of 150 GgC over Feb.—Nov. 2019, as opposed to the previously reported loss of 133 GgC. See lines 253—255 of the revised manuscript with tracked changes. The adjustment in $\Delta GPP_{FluxSat}$ showed a different temporal evolution, more closely following the reduction estimated through the two SIF-based approaches.

We have update Figures 4a and 4b in the revised manuscript to reflect these changes. Additionally, we have modified the discussion of $\Delta GPP_{FluxSat}$ over time in lines 247—248 of the revised manuscript with tracked changes.

Kind regards – Juliëtte Anema