RC2

In the manuscript titled "Enhancing Long-Term Vegetation Monitoring in Australia: A New Approach for Harmonising and Gap-Filling AVHRR and MODIS NDVI", Burton et al. reconstructed new harmonised NDVI datasets in Australia using the GBM method. The manuscript and figures are well prepared. I appreciate the extensive work conducted in this study, like, comparing existing datasets, producing new datasets and applications. However, from my perspective, this paper may still lack sufficient novelty to warrant publication in ESSD. Below, I outline my main concerns and provide point-to-point comments.

Main concerns:

<u>RC2-1:</u> In the context of the existing abundance of NDVI datasets such as VIP15 NDVI, GIMMS NDVI3g and the latest PKU NDVI, authors still aim to produce new NDVI datasets, which is challenged. I encourage this work, but authors fail to show strong motivations for doing so (like, data unavailability or any issues present in existing datasets).

We wholeheartedly agree that there is an abundance of existing global NDVI datasets, and we have gone to considerable effort to include many of the most prominent datasets in a detailed intercomparison. In the introduction, we list several well-known discrepancies with existing NDVI products (lines 66-70), and also make note that the recent PKU-GIMMS product has yet to be widely assessed by the community owing to its recent release. This is why we set our first objective of the study to assess many of the pre-existing datasets to determine if they are suitable for studying the long term biogeophysical impacts of global change on Australia's terrestrial vegetation. Note that while there are many studies at the global scale that assess existing NDVI products, none have focused on Australia, and we see this inter-comparison as itself a valuable contribution to the Australian research community.

Ultimately, we conclude that GIMMS3g, CDR, and GIMMS-PKU have significant deficiencies (sensor transition issues, poor correlation, and/or high error with MODIS). GIMMS-PKU-consolidated offers a real improvement over other products, however, GIMMS-PKU-consolidated still has shortcomings, primarily that it does not display realistic inter-annual variability in the 1982-2001 period, and displays a lower trend in annual average NDVI from 1982-2013 than GIMMS3g and AusENDVI (figure and comments on annual average trends are in the next response, RC2-2). Hence, we argue there are further advances that can be made by optimising to the regional scale, by including a range of new features such as climate variables in the calibration, and by developing a more robust gap-filling technique. In short, our aim is to develop the best possible NDVI dataset optimised for the needs of the Australian research community, that iteratively improves on previous datasets, just as GIMMS-PKU iteratively improved on GIMMS3g.

<u>RC2-2:</u> According to the results (like, figures 2 & 8), I think PKU-consolidated dataset has been produced well, and compared to PKU data, your dataset does not show any significant and necessary improvements. Therefore, I would suggest highlighting clear improvements than other existing datasets.

The recent release of the GIMMS-PKU-consolidated dataset showed significant improvements over previously existing global NDVI datasets as it effectively remediated some sensor transition issues, aligns well with MODIS, and, at the global scale, better reproduced the greening trend observable in MODIS. However, over Australia, it is our contention that it fails to reproduce realistic inter-annual variability in the pre-MODIS era as indicated by its lack of agreement with the Landsat record in Figure 3a, and the distinct lack of rainfall-driven inter-annual variability as shown in Figure 3b and Figure 8b, respectively. This is important as the terrestrial biosphere's response to climate extremes (droughts, heavy rainfall) is of paramount importance to study given the changing frequency of climate extremes in Australia (Lewis et al. 2017). How Australia's ecosystems are responding to these changes may depend on the shifting seasonality of rainfall, warming air temperatures, and increasing atmospheric CO_2 concentrations which all affect plant physiology. We cannot effectively study these impacts and mechanisms (at the continental scale) if vegetation variability from 1982-2000 is artificially subdued.

In the figure below we develop the statistical relationships between twelve-month rolling mean standardised rainfall and NDVI anomalies, averaged across Australia for different periods and different products. If we consider the slope of the linear relationship between rainfall and NDVI to be a reasonable approximation of the sensitivity of NDVI to water supply (and we assume there should be approximate stationarity in these relationships), then AusENDVI-clim in the 1982-2000 period (c) displays a similar sensitivity and correlation as MODIS does in the 2000-2022 period (b). Contrast this with GIMMS-PKU-consolidated which has a substantially lower sensitivity in the 1982-2000 period (d) than it does in the 2000-2022 period (e) (approximately half the sensitivity). While we may expect some changes in water-supply sensitivity over the decades due to effects such as CO_2 fertilisation, a doubling of water-supply sensitivity is highly unlikely. It is clear that AusENDVI is responding more realistically to rainfall-driven interannual variability than GIMMS-PKU-consolidated, which we consider an iterative advancement. We will include these scatter plots in an updated manuscript, along with the time series of AusENDVI-clim and GIMMS-PKU-consolidated anomalies (i.e., we will update figure 8 with these plots and adjust the results/discussion accordingly).

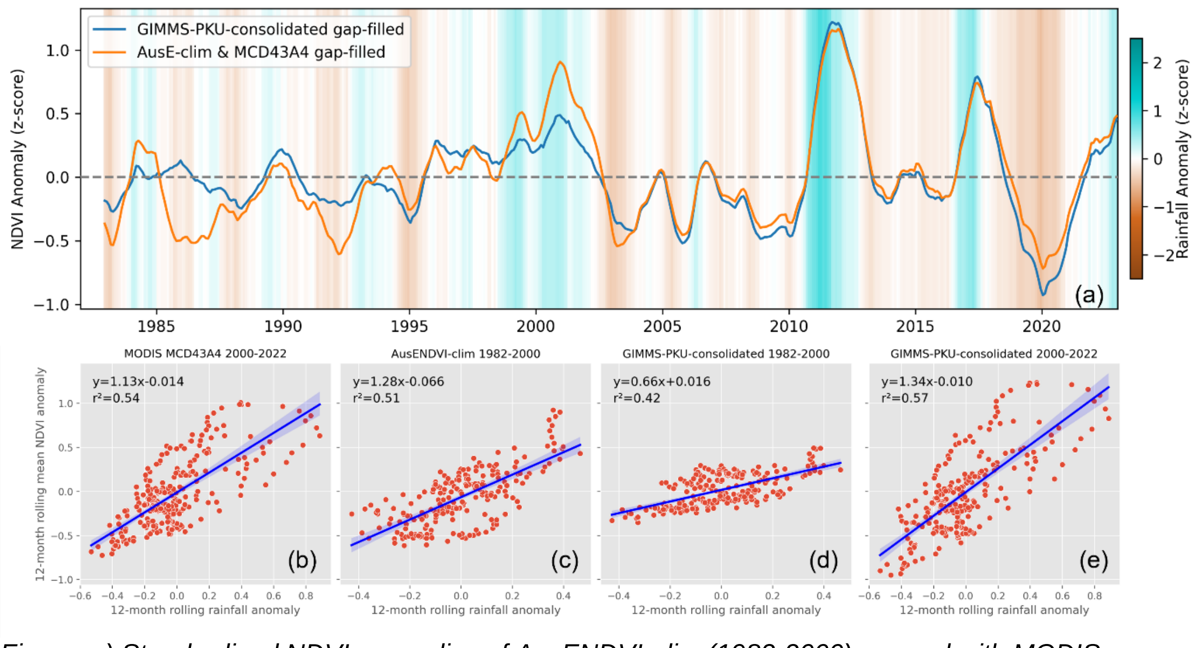

Figure: a) Standardised NDVI anomalies of AusENDVI-clim (1982-2000) merged with MODIS MCD43A4 (2000-2022), and GIMMS-PKU-consolidated. Both datasets have been gap-filled identically following the methods described in section 2.3.   b-d) Relationships between twelve-month *rolling mean standardised rainfall and NDVI anomalies averaged across Australia for different periods. Rainfall, AusENDVI and GIMMS-PKU-consolidated anomalies have been calculated against a 1982-2022 baseline. MODIS NDVI anomalies have been calculated against a 2000-2022 baseline. The relationship y=mx+c denotes the linear regression slope between rainfall and NDVI anomalies where y is NDVI anomalies, x is rainfall anomalies, and m is the slope coefficient. The slope coefficient can be considered an approximation of the sensitivity of NDVI to anomalous water supply.*

Additionally, in the second figure below we show the annual average NDVI trends across Australia for the assessed NDVI products. Trends in the two GIMMS-PKU products are less than half those of MODIS, GIMMS3g, and AusENDVI. This result reinforces our assertion that no pre-existing AVHRR-based NDVI product can both reproduce close agreement with the MODIS record while simultaneously reproducing satisfactory results in the pre-MODIS era. We aim to include the annual average trend analysis in a revised manuscript.

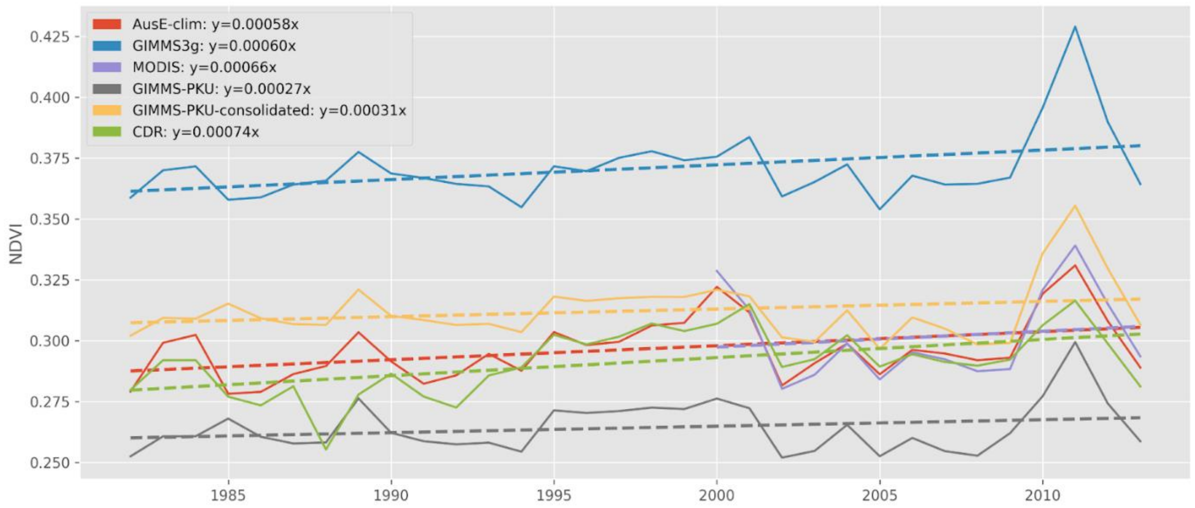

Figure: Annual average NDVI trends summarised over Australia for the overlapping period of 1982-2013. All data gaps have been matched between datasets and datasets have been reprojected to match the resolution of GIMMS3g. Trend lines have been fitted using ordinary least-squares regression and coefficients are expressed in terms of NDVI yr^{-1}.

To summarise, the advantages of AusENDVI are that: 1) it closely reproduces the MODIS record in terms of seasonality, interannual variability, and trends in annual-average NDVI, 2) it reproduces anomalies in the Landsat NDVI record in the pre-MODIS era (back to 1988), and shows realistic rainfall-driven interannual variability back to 1982, 3) gap-filling in AusENDVI does not rely on methods such as filling with a climatology, spatial interpolation methods, or lengthy temporal interpolation methods that are unreliable where wide-spread and lengthy data-gaps occur, 4) it has a higher spatial resolution than any of the GIMMS datasets and is built using inputs that apply the full suite of atmospheric and BRDF corrections, and 5) the methods and code for its development are entirely open-sourced. No other existing product can lay claim to all these attributes which is why we argue AusENDVI is a worthwhile addition to the suite of NDVI products available.

Other comments:

<u>RC2-3:</u> **No ground observations (like, Flux or PhenoCam sites) to validate your data?**

It is unlikely that eddy-covariance flux tower GPP would have a proportional relationship with NDVI at the 5 km scale, and across the many different land covers (Camps-Valls et al 2021). Likewise, the small phenocam network in Australia does not record NDVI values. Instead, they record RGB images that can be converted to 'green chromatic coordinate' values but GCC values are not directly comparable to NDVI (Hufkens et al. 2018, St Peter et al. 2018). Regardless, there still exists a large mismatch in spatial and temporal scales between phenocams and AusENDVI (or any other AVHRR NDVI dataset, the area of pixels in CDR-AVHRR are ~25 km^2). Hence, there is no ground validation data for an independent assessment of our data. However, note that MODIS MCD43A4 surface reflectance data (from which we calculate NDVI as the response variable for the harmonisation) is a well-calibrated and validated remote sensing product, and the validation performed in our study is based on random pixels selected from MODIS. Likewise, we also include a comparison with the Digital Earth Australia Landsat surface reflectance product as this product has all of the same types of corrections (atmospheric, BRDF etc.) (Byne et al. 2024) as MODIS MCD43A4 and is therefore a fair and independent inter-comparison dataset.

<u>RC2-4:</u> **For any designed steps (e.g., gap filling), it is expected to see the comparison of results for before and after processing (can refer to the guide: <u>https://lpdaac.usgs.gov/documents/1328/VIP_User_Guide_ATBD_V4.pdf</u>).**

For the gap-filling, we will insert the figure shown in our response to RC1-3. Figure A4 in the current manuscript shows the time-series of CDR-AVHRR before and after the calibration/harmonisation, averaged across all of Australia and broken down by bioclimatic region. We are open to including this in the main part of the manuscript at the editor's discretion.

<u>RC2-4:</u> **Add a flowchart to summarize each step and processing.**

We thank the reviewer for this suggestion and we will include in the revised manuscript the flow-chart shown in our response to RC1-1.

<u>RC2-5:</u> **Add some quantified results in the abstract to show the reliability/enhancement of your datasets.**

We will add the statistics from Figure 4 to the abstract to show the model agreements with observation, along with the statistics from Figure A5 that shows the agreement between the synthetic NDVI and observations.

<u>RC2-6:</u> **Lines 30-35, provide spatial and temporal resolutions information for your 41-year dataset.**

We will include the spatial and temporal resolution in the abstract in a revised manuscript.

References

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