

We would like to express our gratitude to the editor and reviewers for their efforts in handling and commenting on our manuscript. We highly appreciate the insightful and helpful feedback, which has significantly helped improve our manuscript. Below, we provide detailed responses along with the suggested changes to our manuscript.

Response to Reviewer #2's comments

General comments

This submission aims at building a daily 30-m Landsat data record (2000-2022) based on Landsat 5,7,8,9 and MODIS for gap filling. Authors made sure that data are pre-processed (with AC and BRDF) and harmonized. The main pillars of the data is that they are daily at 30 m and span the 20+ years. While this dataset will certainly find a lot of applications and might be valuable to the community, and I applaud authors for taking on this challenge, in my opinion, the description of this dataset is exaggerated (e.g., daily component) and authors do not provide evidences that this is actual daily data. You cannot use 8-(16)-day data to prove that your dataset is actual daily because you should have available daily reference data. I think this is one of the areas that authors did not work through and claim that your dataset resemble actual daily data is false. Maybe, it would have made sense to focus on regular 8-day composites. Maybe, the problem of generating daily data from 8-/16-day Landsat does not have a solution. Certainly, MODIS can help in certain regions, but I have huge doubts about its applicability globally given discrepancies in spatial resolution. Furthermore, even MODIS, majority of users use 8-day or 16-day composites given that MODIS acquires twice per day (Terra/Aqua). It's done because of clouds and because decrease in spatial resolution of the viewing angle (which increases with the cycle 1-15, and nadir only every 16 days). There are also some very dubious choices (e.g., moving the grid) . From CC comments, one can see obvious artifacts - it's understandable, from global product you can always find errors. But, as mentioned above, it's not real daily product, you did not provide evidences to claim it. I suggest authors to substantially re-work this and give a good thought on what real problem you are trying to solve and provide tangible solution that can be validated.

We sincerely thank the reviewer for the valuable feedback, which has greatly helped us to improve the quality of this manuscript. Following your suggestions, we have made extensive modifications to our manuscript to enhance the clarity of our results. The line numbers mentioned below refer to the revised manuscript with the changes highlighted.

(i) We agree that the SDC is not equivalent to actual daily 30-m EO dataset. Rather, it is an estimation based on Landsat and MODIS time series observations. By developing improved reconstruction algorithms and incorporating more useful priors/constraints, we aim to enhance the estimation accuracy as much as possible. However, achieving 100% accuracy is not feasible since the information provided in the input data is usually incomplete. The effective temporal resolution of SDC depends on the quality of input Landsat and MODIS data, which can vary in space and time. We have modified the descriptions of the daily component and revised the content in Section 5.3 to inform readers about these limitations.

(ii) Indeed, there is no daily 30-m reference dataset available. The near-daily 500-m MODIS dataset should not be used as reference data since it has been employed as input data for the generation of SDC. Therefore, we employed the leave-one-out validation method, which has been widely used to evaluate the performance of MODIS-Landsat fusion algorithms. The calculated metric values from the leave-one-out validation can serve as an indicator of the data quality of reconstructed datasets. Moreover, we also cross-compared SDC with the HLS products, which provide 30-m observations with a 2-3-day revisit frequency.

(iii) This study aims to develop a global, 30-m, seamless dataset of surface reflectance by combining Landsat and MODIS products. We attempt to find an effective approach that can preserve the temporal information and even enhance the effective temporal resolution by incorporating MODIS data. There are certainly estimation errors, and the SDC is not equivalent to actual daily 30-m EO data. Despite this, incorporating near-daily 500-m MODIS data can indeed enhance the monitoring of rapid land cover changes, such as crop harvests. We presented examples showing that using SDC reduces the time gap for confirming land cover changes, compared to using Landsat data alone. We agree that in some situations the information provided by coarse-resolution MODIS data will not be helpful for Landsat reconstruction. Therefore, we applied multiple constraints in our model described in **Equations 8-9** to ensure that our estimations are at least no worse than the interpolated Landsat images.

(iv) The issues presented in the CC comments are caused by undetected residual clouds. The referred MGRS tile 20MQB is located in Brazil, a cloudy region, with input data from the year 2000. The atmospheric correction algorithm LEDAPS for Landsat TM/ETM+ does not perform as well as the LaSRC for Landsat OLI (Vermote et al., 2018). Additionally, there are more cloud omission errors in Landsat TM/ETM+ observations due to the lack of a cirrus band (Zhu et al., 2015a). We have revised the content in Section 5.3 to inform users about the impacts of atmospheric correction and cloud detection algorithms. The data quality of the SDC dataset is significantly better in most other regions and years.

Specific comments

1. "It is noteworthy that our adopted grid slightly deviates from the Sentinel-2 grid. Since the original Landsat coordinate system exhibits a half-pixel (15 meters) offset relative to the Sentinel-2 grid, we expanded and shifted the original MGRS grid by 15 meters in each direction to align with the Landsat coordinate system."

First, there is no shift; it's what is used for referencing a pixel value: center in Landsat and UL in S2 (in grid) (also what is used by default in GDAL). It was a poor decision to shift the grid. Whereas, if you selected MGRS as a coordinate grid, you should have re-projected Landsat (like HLS) into MGRS. Such shift can cause artifacts when comparing to the HLS data.

Response 1: Thank you for pointing this out. We have revised the related content in this paragraph to clarify the differences. The USGS aligns the UTM coordinate origin with a pixel center, while the ESA aligns it with a pixel corner. The HLS products use the Sentinel-2 grid directly, requiring Landsat data to be resampled using cubic convolution to re-align Landsat pixels (HLS product documentation, https://lpdaac.usgs.gov/documents/1698/HLS_User_Guide_V2.pdf). We expanded the Sentinel-2 tiles by 15 meters in each direction to align them with the original Landsat coordinate system, minimizing the need for resampling Landsat data. For most Landsat images, only image cropping is needed to load them into our grid, since they are in the same UTM zone and both reference the UTM coordinate origin with a pixel center.

Changes in manuscript: Lines 176-181, changed from *"Since the original Landsat coordinate system exhibits a half-pixel (15 meters) offset relative to the Sentinel-2 grid, we expanded and shifted the original MGRS grid by 15 meters in each direction to align with the Landsat coordinate system."*

to

"The original Landsat coordinate system aligns the UTM coordinate origin with a pixel center, while the Sentinel-2 grid aligns it with a pixel corner (Claverie et al., 2018). We expanded the Sentinel-2 tiles by 15 meters in each direction to align them with the original Landsat coordinate system, minimizing the need for resampling Landsat data."

2. "Therefore, our approach aims at building multiple transformation models for each MGRS tile and each spectral band separately."

Building models per MGRS tile might introduce issues re spatial consistency. Did you check the impact

of such an approach on the overlapping areas (between tiles)? How are consistent those temporally to reflect land cover changes?

Response 2: Thank you for your comment. We used time series overlap of ETM+ and OLI observations from neighboring MGRS tiles to build linear transformation models. This approach helps improve stability and mitigate the issue of spatial inconsistency between neighboring tiles. In some MGRS tiles where there is no ETM+ and OLI overlap, we can only rely on data from neighboring tiles. The calibration and subsequent processing steps for each tile are independent, including the overlapping areas. Therefore, it would not introduce temporal variations into the reflectance time series in these overlapping areas.

Changes in manuscript: Lines 255-256, added “*This step helps improve stability and mitigate the issue of spatial inconsistency between neighboring MGRS tiles.*”

3. I'm very skeptical about the applicability of MODIS gap-filling for Landsat on global scale. First, almost all existing approaches, including yours, does account for changes in spatial resolution with different angles. In reality, 500-m pixel can actually decrease up to 2 km one - see <https://doi.org/10.1109/TGRS.2016.2604214>

So, your assumption " the basic assumption of uROBOT is that the MODIS image C can be accurately approximated by a linear combination of other similar MODIS images in the input timeseries data" is only valid under the condition that spatial resolution is invariant. That's not the case, especially in cloud-prone regions. Another issue that will not work in areas of small ag fields, e.g., Arica, SE Asia, etc. I have seen multiple times examples when a bare ground field between two vegetative fields will be brightened in MODIS when resolution decreases. And used MODIS-based vegetation signal for Landsat will introduce huge errors. Therefore, a study must be conducted to explore how spatial resolution impacts restoration.

Response 3: Thank you for your comment. Indeed, the effective spatial resolution of MODIS observations can vary significantly over time. Even after BRDF normalization and temporal smoothing, these effects cannot be perfectly mitigated. Therefore, we are not directly using MODIS data to fill the data gaps in Landsat images in this study. Instead, we have adopted two constraints (i) and (ii) in the optimization problem below, utilizing MODIS information to facilitate the reconstruction of unobserved Landsat images.

$$\min_{\alpha} |C_p - D_C \alpha|_2^2 + \lambda |\alpha|_1 + \beta (|F_{interp} - D_F \alpha|_2^2) + \mu (|F_p^+ - D_{F^+} \alpha|_2^2) \quad (8)$$

- (i) $|C_p - D_C \alpha|_2^2$: the coefficient vector α should be consistent with the MODIS representation;
- (ii) residual distribution $\hat{F}_p = D_F \alpha + (C_p - D_C \alpha)$: the low-frequency components of \hat{F}_p should be consistent with C_p ;
- (iii) $|\alpha|_1$: α should be sparse;
- (iv) $|F_{interp} - D_F \alpha|_2^2$: α should be consistent with the representation of F_{interp} , to ensure temporal continuity;
- (v) $|F_p^+ - D_{F^+} \alpha|_2^2$: α should be consistent with the representation of observed part F_p^+ .

Reconstructing missing Landsat data is an under-determined problem, meaning there can be infinitely many possible solutions. By using 500-m MODIS images as “guidance”, we can narrow down the solution space and make more accurate estimations. However, the information provided by 500-m MODIS data is usually incomplete for perfect reconstruction of 30-m Landsat images. Therefore, more useful constraints/priors, such as those in **Equation 8**, are needed to ensure that the obtained results are as accurate as possible. We agree that in some situations the information provided by coarse-resolution MODIS data will not be helpful for Landsat reconstruction. Therefore, we applied multiple constraints in our model described in **Equations 8-9** to ensure that our estimations are at least no worse than the interpolated Landsat images.

We have conducted experiments to study how the spatial resolution of MODIS input data impacts SDC reconstruction accuracy. The conclusion is intuitive: the usable information reduces as the spatial resolution of input MODIS data decreases, leading to higher level of uncertainty and prediction errors. We agree that the view angle information of MODIS data used for SDC restoration should be added to the QA band to inform users about the potential variations of restoration accuracy.

Changes in manuscript: Lines 605-608, added

“Additionally, the effective spatial resolution of MODIS observations changes significantly due to the variations of view angles (Pahlevan et al., 2017). Even after BRDF normalization and temporal smoothing, these effects cannot be perfectly mitigated. The effective temporal resolution of SDC depends on the quality of the input Landsat and MODIS data, which can vary in space and time.”

Lines 346-348, added

“In regions with frequent cloud cover, the scarcity of cloud-free observations can pose a challenge. To address this, the temporal continuity constraint $\beta|F_{interp} - D_F\alpha|_2^2$ and the residual distribution in Equation (9) ensure that our estimations are consistent with C_p and are at least as accurate as the interpolated results F_{interp} .”

4. Section 5.3 must be re-written as it does not show limitations but rather what have not been done. There should be paragraphs re snow, re coastal regions and water, as AC algorithms do not work the best there (especially for snow as retrieval of aerosols is extremely difficult there). Furthermore, probably this product is not applicable to detecting rapid changes (daily) in land cover such as constructions as it will depend on actual acquisitions (and not blended daily). It will probably will not allow to detect "daily" burned fields or harvested fields because the signal will change in 2-3 days, or landslides, or iceberg movement, or fire propagation - anything that truly changes every hour or day. Again, in reality your daily product will not allow (please, prove me wrong!) detection of these events (at daily basis) which require true daily data.

Response4: Thank you for your comment. We have revised the content in Section 5.3 to acknowledge that the effective temporal resolution of SDC can vary depending on the input data conditions. We also informed readers that atmospheric correction algorithms may not work optimally in areas with snow and water bodies. The LEDAPS atmospheric correction algorithm for Landsat-5,7 does not perform as well as the LaSRC for Landsat-8,9 (Vermote et al., 2018). Additionally, the Fmask algorithm for Landsat-5,7 is less effective compared to its performance for Landsat-8,9, due to the absence of the cirrus band (Zhu et al., 2015a). Residual aerosols and omitted clouds in Landsat input data can introduce temporal noise and spatial artefacts in SDC data.

We agree that the SDC is not equivalent to actual daily 30-m EO data. It is an estimation based on Landsat and MODIS time series observations. By developing improved reconstruction algorithms and incorporating more useful priors/constraints, we aim to enhance the estimation accuracy as much as possible. However, achieving 100% accuracy is not feasible since the information provided in the input data is usually incomplete. The effective temporal resolution of SDC depends on the quality of the input Landsat and MODIS data, which can vary in space and time.

30-m 8/16-day Landsat < SDC < actual daily 30-m EO data

(we aim to minimize the gaps between the SDC and actual daily 30-m EO data as much as possible)

Despite these limitations, SDC has notable strengths. As demonstrated in the figure below, incorporating near-daily 500-m MODIS data can indeed enhance the monitoring of some rapid land cover changes, such as crop harvests. Although there are differences between reconstructed SDC data and actual HLS S30 observations, using SDC reduces the time gap for confirming land cover changes, compared to using Landsat data alone. Moreover, SDC is consistent in both spatial and temporal dimensions, making it analysis-ready for subsequent applications.

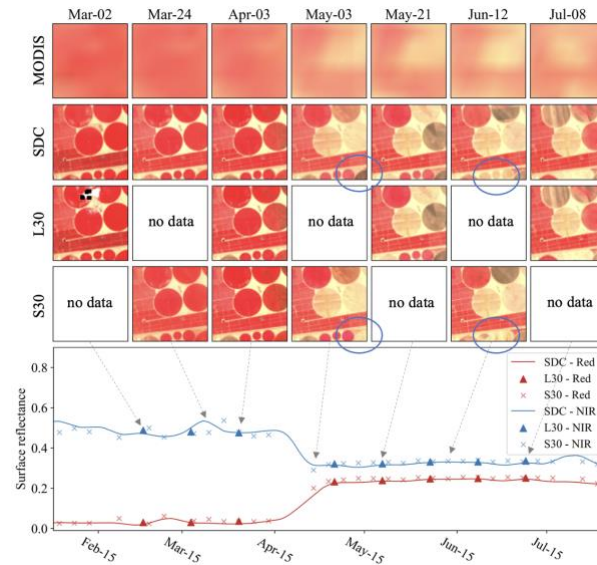


Figure. An example from the manuscript. Blue circles highlight the differences between reconstructed SDC and actual Sentinel-2 observations.

Changes in manuscript: Lines 600-611, revised the content in Section 5.3, to inform readers about the above-mentioned limitations of SDC,

“The SDC is not equivalent to actual daily 30-m Earth observations data. It is an estimation based on Landsat and MODIS time series observations. Reconstructing missing Landsat data is an under-determined problem, meaning there can be infinitely many possible solutions (Shen et al., 2015). By using 500-m MODIS images as “guidance” and applying the constraints presented in Equation (8), we can narrow down the solution space and make more accurate estimations. However, achieving 100% accuracy is not feasible since the information provided in the input data is usually incomplete. Additionally, the effective spatial resolution of MODIS observations changes significantly due to the variations of view angles (Pahlevan et al., 2017). Even after BRDF normalization and temporal

smoothing, these effects cannot be perfectly mitigated. The effective temporal resolution of SDC depends on the quality of the input Landsat and MODIS data, which can vary in space and time.

The LEDAPS atmospheric correction algorithm for Landsat TM and ETM+ does not perform as well as the LaSRC for Landsat OLI (Vermote et al., 2018). Additionally, the Fmask algorithm for Landsat-5,7 is less effective compared to its performance for Landsat-8,9, due to the absence of the cirrus band (Zhu et al., 2015a).”

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