

ChatEarthNet: A Global-Scale Image-Text Dataset Empowering Vision-Language Geo-Foundation Models

By Z. Yuan, Z. Xiong, L. Mou, X. X. Zhu

General remarks to all reviewers and editors:

We sincerely thank the editors and anonymous reviewers for their valuable comments and suggestions. Below, we provide point-by-point responses to the reviewers' comments. The reviewers' comments are in **black**, and our responses follow in **blue**. The revised parts are marked in **red** in the manuscript.

Reviewer #1:

The authors propose a land cover dataset, ChatEarthNet, built by pairing Sentinel-2 patches with their corresponding WorldCover masks, which contain 12 land cover classes.

The originality comes from providing the land cover data, not directly a a bitmap, but as a textual description extracted from the WorldCover map by means of a large language model (LLM).

Specifically, they use two different models: ChatGPT-3.5, an LLM that can only receive text as input, and ChatGPT-4V, a vision LLM (VLLM) that is able to understand both text and images. Due to cost, they provide 163k images with captions generated by GPT-3.5 and 10k by GPT-4V.

The Sentinel-2 patches are obtained from the dataset SatlasPretrain.

Main comments:

1. The paper describes the prompting process, which differs for GPT-3.5 and -4V. Although the prompt is provided, some details are missing in relation to the exact construction of the outputs of algorithms 1 to 3, since the exact wording of the prompt produced by these algorithms is not given.

R: We appreciate the reviewer's comment. We have included the exact wording produced by algorithms 1 to 3 in Appendix A. Below are examples of the outputs generated by these algorithms:

An example of the exact wording of the prompt generated by Algorithm 1:

An example of prompt output by Algorithm 1

grass; tree; developed area; crop; water; bare land.

The **top left** mainly contains the following land cover types, in descending order of content:

grass (medium part), tree (medium amount), and developed area (medium amount).

The **top right** mainly contains the following land cover types, in descending order of content:

tree (medium quantity), grass (medium amount), and developed area (small amount).

The **bottom left** mainly contains the following land cover types, in descending order of content:

grass (medium amount), tree (medium fraction), and developed area (medium fraction).

The **bottom right** mainly contains the following land cover types, in descending order of content:

crop (medium part), grass (medium portion), and developed area (small portion).

The **middle** mainly contains the following land cover types, in descending order of content:

tree (medium part), grass (medium portion), and developed area (medium fraction).

An example of the exact wording of the prompt generated by Algorithm 2:

An example of prompt output by Algorithm 2

crop: top left: 72.27% top right: 43.16% bottom left: 41.78% bottom right: 58.15% middle: 39.85%

grass: top left: 10.02% top right: 26.73% bottom left: 36.18% bottom right: 16.22% middle: 27.62%

developed: top left: 14.67% top right: 24.27% bottom left: 15.21% bottom right: 21.97% middle: 23.75%

water: top left: 1.68% top right: 3.22% bottom left: 2.73% bottom right: 0.21% middle: 3.45%

bare: top left: 0.12% top right: 0.21% bottom left: 0.11% bottom right: 0.29% middle: 0.28%

tree: top left: 1.04% top right: 1.06% bottom left: 3.98% bottom right: 2.92% middle: 4.46%

An example of the exact wording of the prompt generated by Algorithm 3:

An example of prompt output by Algorithm 3

top left distribution: crop: 0.72; developed: 0.15; grass: 0.10; water: 0.02; tree: 0.01; bare: 0.00;

top right distribution: crop: 0.43; grass: 0.27; developed: 0.24; water: 0.03; tree: 0.01; bare: 0.00;

bottom left distribution: crop: 0.42; grass: 0.36; developed: 0.15; tree: 0.04; water: 0.03; bare: 0.00;

bottom right distribution: crop: 0.58; developed: 0.22; grass: 0.16; tree: 0.03; bare: 0.00; water: 0.00;

middle distribution: crop: 0.40; grass: 0.28; developed: 0.24; tree: 0.04; water: 0.03; bare: 0.00;

Bold and underline are used to improve readability. Note that in Algorithm 2, we calculate the percentage of a specific land cover in each patch, not the percentage of one land cover in the entire image. Therefore, the sum of the percentages is not 1. These examples are added to Appendix A to provide a clear understanding of how the exact outputs of the algorithms are used to construct the prompts.

2. Section 2.5 briefly mentions that manual verification is applied in order to check that the LLM correctly followed the prompt instructions. However, it is not clear how many times the prompt had to be modified, and the kind of modifications that were required.

R: Thanks for the comment. To clarify the potential confusion, the manual verification process described in Section 2.5 aims to ensure the quality and correctness of the generated captions, not modify the prompts. Once the prompts were finalized, we did not further modify them. Instead, our manual verification process focuses on reviewing and correcting the generated captions to ensure they meet our quality standards.

Unfortunately, we did not track the number of samples where modifications were made for captions, making it difficult to provide exact answers. However, we would like to emphasize the reason for manual verification: when using ChatGPT-4V, we combine four images into a single API request. We adopt this approach due to the constraints on API usage for ChatGPT-4V (with a tier 1 limit of 500 requests per day by February 2024) and to enhance the efficiency of text generation. Despite providing specific instructions for ChatGPT-4V to treat each image individually, it occasionally makes mistakes by describing comparisons between images, which is not our intention. In such cases, manual corrections are necessary. In contrast, when using the ChatGPT-3.5 model (with a tier 1 limit of 10k requests per day by February 2024), each image is processed through individual API requests.

3. Although the authors claim that “10k high-quality image-text pairs using ChatGPT-4V are sufficient for fine-tuning large vision-language models”, they do not provide any evidence for this. There is not evaluation of the properties of a model trained with the proposed dataset, making it impossible to judge the quality of the representation that can be learned with it, in comparison with a model trained directly for land cover mapping using the WorldCover data.

R: Thanks for the insightful comments. We appreciate the opportunity to provide further evidence and clarification regarding the quality of our dataset. Our claim that the dataset consists of high-quality image-text pairs is grounded in the following key factors:

- 1) Our dataset provides rich descriptions of the Sentinel-2 images, which contain information about shapes, spatial relationships, distributions, and the main theme of the image, which can be used to train or fine-tune multimodal large language models (MLLMs). Regarding the comparison with traditional segmentation models trained using WorldCover data, a key difference is evident: traditional segmentation models trained on WorldCover data lack the ability to generate rich linguistic descriptions of shapes, spatial relationships, and distributions of land cover types. This limitation indicates the superiority of our dataset in capturing and conveying complex geospatial information through natural language.
- 2) To further support our claim, we provide experiments to fine-tune MLLMs to prove that the proposed dataset can be used to enhance the development of large vision language models. As shown in Table 2, compared with existing MLLMs in the zero-shot setting, like LLaVA-v1.5 [1], MiniGPT-v2 [2], MiniGPT-4 [3], and GeoChat [4], the fine-tuned models using ChatEarthNet (ChatGPT-4V version) can achieve clearly better performance. The results indicate that the proposed ChatEarthNet dataset is

not only useful for downstream applications but also effective as a benchmark to evaluate different MLLMs. Please refer to *Comment #4* for more details.

- 3) It is worth noting that the rich descriptions with natural language on Sentinel-2 images in our dataset provide opportunity to non-expert users to understand the sentinel images, who may have difficulty understanding WorldCover labels.

Table 2. Performance comparison of different models on the ChatEarthNet (ChatGPT-4V Version) test set.

Models	Bleu-1	Bleu-2	Bleu-3	Bleu-4	CIDEr	METEOR	ROUGE_L	SPICE
LLaVA-v1.5	0.285	0.116	0.040	0.014	0.012	0.104	0.186	0.093
MiniGPT-v2	0.279	0.116	0.041	0.015	0.009	0.104	0.180	0.091
MiniGPT-4	0.175	0.072	0.023	0.008	0.000	0.116	0.180	0.079
GeoChat	0.199	0.088	0.034	0.011	0.005	0.067	0.126	0.083
MiniGPT-4 (ChatEarthNet)	0.310	0.184	0.113	0.071	0.001	0.209	0.254	0.186
GeoChat (ChatEarthNet)	0.445	0.269	0.170	0.109	0.094	0.208	0.286	0.211

4. The authors conclude that “ChatEarthNet is a valuable resource for training and evaluating vision-language geo-foundation models for remote sensing”. However, it is not fully clear how this evaluation would work. To be able to conclude this, I suggest the authors do use the dataset to evaluate existing models, such as RemoteCLIP [1], RSCLIP [2] and others.

R: We thank the reviewer for the valuable suggestion. We agree that demonstrating ChatEarthNet’s utility for evaluating vision-language geo-foundation models is crucial. In response to the suggestion, we have conducted benchmarking experiments using various existing models on the proposed dataset.

Regarding the reviewer’s recommendations to include RemoteCLIP [1] and RSCLIP [2], we appreciate the suggestion. However, the pretrained RSCLIP model is not publicly available at this time. Reproducing its training process would require significant computational resources, which presents substantial challenges. As such, direct evaluation of RSCLIP is currently not feasible.

As for RemoteCLIP, while it is a CLIP-based model suitable for vision tasks, applying it directly to ChatEarthNet, which contains long and detailed descriptions, would require extensive alignment with large language models through training connectors on a sizable dataset. This process is resource-intensive and beyond the scope of this paper. We thank the reviewer for pointing out this, and we have added explanations in the revised version, as presented below.

To address the reviewer’s concerns, we have conducted benchmarking experiments using widely established MLLMs. Specifically, we evaluated several MLLMs, including LLaVA-v1.5 [3], MiniGPT-v2 [4], MiniGPT-4 [5], and GeoChat [6]. These evaluations further support our conclusion that ChatEarthNet is a valuable resource for training and evaluating

vision-language geo-foundation models for remote sensing. We have added the experimental part to the revised paper as follows.

“To demonstrate the effectiveness of ChatEarthNet in evaluating multimodal large language models, we conduct benchmarking experiments using a range of existing models. Given that ChatEarthNet includes long and detailed descriptions, it is not well-suited for evaluating CLIP-based vision-language models like RemoteCLIP [1] and RS-CLIP [2]. Therefore, we focus on evaluating widely used multimodal large language models, including LLaVA-v1.5 [3], MiniGPT-v2 [4], MiniGPT-4 [5], and GeoChat [6]. All experiments are performed using the ChatGPT-4V version of our dataset, which allows us to conduct extensive evaluations across multiple models while significantly reducing computational resource requirements.

Table 2 summarizes the results of these evaluations, detailing the models’ performance across several widely used metrics: BLEU, CIDEr, METEOR, ROUGE-L, and SPICE. We evaluate these models in two experimental settings. The first is a zero-shot transfer setting, where pre-trained models are used to generate captions without any additional training or fine-tuning on the ChatEarthNet dataset. The first four rows in Table 2 present the results of this zero-shot transfer setting. The performance is suboptimal due to the domain gap between the models’ original training datasets and our test dataset. In addition to zero-shot testing, we fine-tune some of these models on the ChatEarthNet dataset (ChatGPT-4V version) and report their performance. The results clearly show that fine-tuning on our proposed dataset significantly improves image captioning performance in the context of remote sensing data. These findings strongly suggest that ChatEarthNet is a valuable resource for both training and evaluating vision-language geo-foundation models in the remote sensing domain.”

Table 2. Performance comparison of different models on the ChatEarthNet (ChatGPT-4V Version) test set.

Models	Bleu-1	Bleu-2	Bleu-3	Bleu-4	CIDEr	METEOR	ROUGE_L	SPICE
LLaVA-v1.5	0.285	0.116	0.040	0.014	0.012	0.104	0.186	0.093
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MiniGPT-4	0.175	0.072	0.023	0.008	0.000	0.116	0.180	0.079
GeoChat	0.199	0.088	0.034	0.011	0.005	0.067	0.126	0.083
MiniGPT-4 (ChatEarthNet)	0.310	0.184	0.113	0.071	0.001	0.209	0.254	0.186
GeoChat (ChatEarthNet)	0.445	0.269	0.170	0.109	0.094	0.208	0.286	0.211

- [1] F. Liu, D. Chen, Z. Guan, X. Zhou, J. Zhu, Q. Ye, L. Fu, and J. Zhou, “RemoteCLIP: A vision language foundation model for remote sensing,” *IEEE Transactions on Geoscience and Remote Sensing*, 2024.
- [2] X. Li, C. Wen, Y. Hu, and N. Zhou, “RS-CLIP: Zero shot remote sensing scene classification via contrastive vision-language supervision,” *International Journal of Applied Earth Observation and Geoinformation*, 2023.
- [3] H. Liu, C. Li, Q. Wu, and Y. J. Lee, “Visual instruction tuning,” *Advances in Neural Information Processing Systems* 36, 2023.

[4] J. Chen, D. Zhu, X. Shen, X. Li, Z. Liu, P. Zhang, R. Krishnamoorthi, V. Chandra, Y. Xiong, and M. Elhoseiny, “MiniGPT-v2: Large language model as a unified interface for vision-language multi-task learning,” *arXiv preprint arXiv:2310.09478*, 2023.

[5] D. Zhu, J. Chen, X. Shen, X. Li, and M. Elhoseiny, “MiniGPT-4: Enhancing vision-language understanding with advanced large language models,” *arXiv preprint arXiv:2304.10592*, 2023.

[6] K. Kuckreja, M. S. Danish, M. Naseer, A. Das, S. Khan, and F. S. Khan, “Geochat: Grounded large vision-language model for remote sensing,” *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, 2024.

Minor comments:

1. In Section 3.2, the authors write that “ChatGPT-3.5 is more dense, covering a wider range of areas”. However, aren’t both datasets obtained by randomly sampling SatlasPretain? Shouldn’t they therefore have roughly the same distribution? If I understand it well, the only difference should be the number of images.

R: Thank you for your question. You are correct. Due to the cost and access limitations of ChatGPT-4V, the number of images used in ChatGPT-4V is significantly lower compared to the number used in ChatGPT-3.5. Regarding the geographical coverage, they basically have roughly the same distribution. The only difference is the density of coverage.

2. In Section 3.3, they authors explore word frequency in the generated captions.

R: The word frequency analysis in Section 3.3 provides valuable insights into the linguistic characteristics of the generated captions.

3. In line 50, “few pairs in the website” should be “few pairs on the web” or “online”.

R: Thank the reviewer for pointing out this. We have revised the relevant sentence to: “However, few pairs on the web provide detailed descriptions for satellite images.” Please kindly check out the revised version.

4. The authors often refer to “land covers”, although may be “land cover types” or “classes” would be more appropriate.

R: We appreciate the reviewer’s suggestions on this point. We agree that “land cover types” or “classes” are more appropriate terms. We have revised the relevant terms in the manuscript.

Reviewer #2:

1. Throughout the paper, the author mentioned image-text datasets many times. Image-text datasets cover multiple different types of annotations, such as image caption, VQA, and visual grounding. Since this paper focuses on image captioning, the writing should be modified accordingly.

R: We appreciate the reviewer’s suggestion on this point. We agree with the reviewer’s understanding of the concept of image-text dataset. Image-text datasets indeed contain multiple types of text annotations, including image captioning, visual question answering, and visual grounding. However, our dataset specifically provides long, detailed descriptions of images, particularly focusing on land cover types and their spatial distribution. While these descriptions are closely related to image captioning tasks, they contain richer information that extends beyond typical captioning tasks. It can be readily used for other generative tasks, such as image-to-text and text-to-image synthesis. In addition, the dataset can also be easily extended to visual question answering by leveraging the capabilities of current large language models. This versatility is why we refer to it as an “image-text dataset,” a high-level term that captures its potential for a range of tasks.

In light of this, we choose to use the broader term “image-text dataset” to reflect the higher-level concept of images paired with textual descriptions. This is consistent with prior works [1]-[5], which also use “image-text dataset” when focusing primarily on image captioning tasks.

[1] D. Qi, L. Su, J. Song, E. Cui, T. Bharti, and A. Sacheti, “ImageBERT: Cross-modal pre-training with large-scale weak-supervised image-text data,” *arXiv preprint arXiv:2001.07966*, 2020.

[2] K. Srinivasan, K. Raman, J. Chen, M. Bendersky, and M. Najork, “WIT: Wikipedia-based image text dataset for multimodal multilingual machine learning,” *Proceedings of the 44th International ACM SIGIR Conference on Research and Development in Information Retrieval*, 2021.

[3] K. Desai, G. Kaul, Z. Aysola, and J. Johnson, “RedCaps: Web-curated image-text data created by the people, for the people,” *arXiv preprint arXiv:2111.11431*, 2021.

[4] Y. Okamoto, H. Toyonaga, Y. Ijiri, and H. Kataoka, “Constructing image-text pair dataset from books,” *arXiv preprint arXiv:2310.01936*, 2023.

[5] Q. Yu, Q. Sun, X. Zhang, Y. Cui, F. Zhang, Y. Cao, X. Wang, and J. Liu, “Capsfusion: Rethinking image-text data at scale,” *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, 2024.

2. The authors use land cover labels from WoldCover products to formulate prompts. The information carried by image captions mainly covers land cover information, this limits the usage of the proposed dataset. This is a big drawback when compared to previous datasets (e.g., RSICap) that provide more diverse information (such as object counting, position, size, and complex reasoning).

R: Thanks for the insightful comments. RSICap [6] is an excellent dataset that offers diverse and detailed annotations, but it has a relatively smaller volume and relies on manual

annotation. In contrast, our dataset leverages automated methods to generate a significantly larger volume of image-text pairs, ensuring broader coverage and scalability. Our dataset consists of satellite images with global coverage and lower resolution. This makes object counting and complex reasoning more challenging due to the granularity of the images.

Although we use land cover labels from WorldCover products to formulate prompts, our dataset also includes detailed descriptions related to position and size. For example: “This image reveals a mix of developed areas and trees, with developed areas showing expansive coverage particularly in the top left, signifying widespread human settlement or infrastructure. Bodies of water are substantially present, especially in the top left, forming large open shapes indicative of lakes or wide rivers. Trees spread significantly across the bottom half, offering a sense of a forested or natural region, while grasslands are present but less dominant. Varying shapes in the pattern of developed areas and the strong presence of water features characterize this image alongside the notable forest coverage.”

In summary, we believe that both RSICap and our dataset offer valuable contributions to the community, but with distinct focuses. RSICap emphasizes high-resolution object recognition, counting, and attribute analysis, while ChatEarthNet focuses on land cover types and global coverage.

[6] Y. Hu, J. Yuan, C. Wen, X. Lu, and X. Li, “RSGPT: A remote sensing vision language model and benchmark.” *arXiv preprint arXiv:2307.15266*, 2023.

3. Information Overlap. To generate image captions, the proposed method divides each image of 256x256 into 5 patches of size 128x128, top-left, top-right, bottom-left, bottom-right, and middle patches. The center patch overlaps with other patches. This causes two issues: 1) duplicated object description; 2) duplicated object counting.

R: We appreciate the reviewer’s comment on this point. In real-world scenarios, it is common for land cover types to span across multiple regions, including overlapping areas. While our method involves dividing the image into patches with some overlap, this does not affect describing each patch individually. Specifically, we divide one image into five patches, including a central one that overlaps with the others, to ensure a comprehensive description of the spatial distribution across the entire image. Without this overlap, the central portion of the image might be overlooked, leading to incomplete coverage of the spatial pattern.

Since our dataset focuses on land cover types, which often lack distinct object boundaries, there is no issue of duplicated object descriptions. We also notice that there are no redundant descriptions in overlapping areas. Additionally, ChatEarthNet does not involve object counting in its captions. Therefore, the overlap does not introduce any issues related to duplicated object counting, ensuring that the dataset remains unaffected in this case.

4. “Moreover, considering the API request limit of ChatGPT-4V, we put four images into one request to generate descriptions more efficiently”. By putting four images into one request, do you mean concatenate the images into one? Merging multiple images will cause undesired interactions between image features caused by self-attention in transformer architecture. As far as I know,

GPT-4V allows 10,000 requests per day, it's therefore not necessary to put four images into one request.

R: Thank you for the insightful comment. To clarify, we do not concatenate four images into one. Instead, we send four separate images in a single API request to ChatGPT-4V. Therefore, there are no interactions between image features at the model level. However, in a few cases, the returned descriptions include comparisons between different images, which is not our intention. To address this, we manually review and correct such descriptions to ensure quality.

In addition, we would like to clarify three points regarding our decision to put four images into a single request when generating captions with ChatGPT-4V.

- 1) Our work began in 2023, and the first version of the manuscript was submitted in February 2024. At that time, for usage tier 1, the limit was set at 500 requests per day, not the 10,000 requests per day that are available now. Given the resource constraints we faced at that time, we chose to put four images into one request to generate descriptions more efficiently.**
- 2) To ensure that the images are described independently, our prompts specifically request: "Generate the four descriptions separately; do not add connections between them."**
- 3) Despite the prompt requesting no interactions between images, some descriptions still contain comparisons among the four images. To ensure quality, we manually check all captions generated by ChatGPT-4V and refine comparison-related captions.**

5. Missing experimental verification. By the current version, it's unclear how this dataset can be used to boost the development of LVLMs in remote sensing. As a benchmark dataset, it's better to show the image captioning performance of existing well-known methods on the proposed dataset.

R: We thank the reviewer for the valuable comment. We agree that demonstrating ChatEarthNet's utility for evaluating vision-language geo-foundation models is crucial. To address the reviewer's concerns, we have conducted additional benchmarking experiments using widely established multimodal large language models (MLLMs). Specifically, we evaluated several MLLMs, including LLaVA-v1.5 [7], MiniGPT-v2 [8], MiniGPT-4 [9], and GeoChat [10]. These evaluations further support our conclusion that ChatEarthNet is a valuable resource for training and evaluating vision-language geo-foundation models for remote sensing. Please kindly check out the revised version as follows.

"To demonstrate the effectiveness of ChatEarthNet in evaluating multimodal large language models, we conduct benchmarking experiments using a range of existing models. Given that ChatEarthNet includes long and detailed descriptions, it is not well-suited for evaluating CLIP-based vision-language models like RemoteCLIP [11] and RS-CLIP [12]. Therefore, we focus on evaluating widely used multimodal large language models, including LLaVA-v1.5 [7], MiniGPT-v2 [8], MiniGPT-4 [9], and GeoChat [10]. All experiments are performed using the ChatGPT-4V version of our dataset, which allows us to conduct extensive evaluations across multiple models while significantly reducing computational resource requirements.

Table 2 summarizes the results of these evaluations, detailing the models’ performance across several widely used metrics: BLEU, CIDEr, METEOR, ROUGE-L, and SPICE. We evaluate these models in two experimental settings. The first is a zero-shot transfer setting, where pre-trained models are used to generate captions without any additional training or fine-tuning on the ChatEarthNet dataset. The first four rows in Table 2 present the results of this zero-shot transfer setting. The performance is suboptimal due to the domain gap between the models’ original training datasets and our test dataset. In addition to zero-shot testing, we fine-tune some of these models on the ChatEarthNet dataset (ChatGPT-4V version) and report their performance. The results clearly show that fine-tuning on our proposed dataset significantly improves image captioning performance in the context of remote sensing data. These findings strongly suggest that ChatEarthNet is a valuable resource for both training and evaluating vision-language geo-foundation models in the remote sensing domain.”

Table 2. Performance comparison of different models on the ChatEarthNet (ChatGPT-4V Version) test set.

Models	Bleu-1	Bleu-2	Bleu-3	Bleu-4	CIDEr	METEOR	ROUGE_L	SPICE
LLaVA-v1.5	0.285	0.116	0.040	0.014	0.012	0.104	0.186	0.093
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[7] H. Liu, C. Li, Q. Wu, and Y. J. Lee, “Visual instruction tuning,” *Advances in Neural Information Processing Systems* 36, 2023.

[8] J. Chen, D. Zhu, X. Shen, X. Li, Z. Liu, P. Zhang, R. Krishnamoorthi, V. Chandra, Y. Xiong, and M. Elhoseiny, “MiniGPT-v2: Large language model as a unified interface for vision-language multi-task learning,” *arXiv preprint arXiv:2310.09478*, 2023.

[9] D. Zhu, J. Chen, X. Shen, X. Li, and M. Elhoseiny, “MiniGPT-4: Enhancing vision-language understanding with advanced large language models,” *arXiv preprint arXiv:2304.10592*, 2023.

[10] K. Kuckreja, M. S. Danish, M. Naseer, A. Das, S. Khan, and F. S. Khan, “Geochat: Grounded large vision-language model for remote sensing,” *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, 2024.

[11] F. Liu, D. Chen, Z. Guan, X. Zhou, J. Zhu, Q. Ye, L. Fu, and J. Zhou, “RemoteCLIP: A vision language foundation model for remote sensing,” *IEEE Transactions on Geoscience and Remote Sensing*, 2024.

[12] X. Li, C. Wen, Y. Hu, and N. Zhou, “RS-CLIP: Zero shot remote sensing scene classification via contrastive vision-language supervision,” *International Journal of Applied Earth Observation and Geoinformation*, 2023.

Minors:

1. ChatGPT-3.5 is not a widely used term. Instead, ChatGPT and gpt-3.5-turbo are more frequently used.

R: Thanks for the valuable comment. In this manuscript, we use “ChatGPT-3.5” to refer to the model technically known as “gpt-3.5-turbo.” Similarly, “ChatGPT-4V” refers to “gpt-4-vision-preview.” These terms are intended to provide a more intuitive understanding of the models’ positions within the ChatGPT series.

We have added the following sentence in the revised manuscript to clarify this as follows.

“In this manuscript, ChatGPT-3.5 refers to the model gpt-3.5-turbo and ChatGPT-4V refers to the model gpt-4-vision-preview.”

2. In line 67, referring image segmentation belongs to visual grounding and therefore should be merged.

R: Thank you for your comment. We believe you may be referring to line 37. While both visual grounding and referring image segmentation are vision-language tasks, they produce different types of outputs. Visual grounding generates a bounding box around the referred object, while referring image segmentation produces a pixel-level mask for the object based on the query. Given this fundamental difference in output, we choose to keep them as separate tasks in the manuscript.

3. In line 44, when mentioning large vision-language foundation models, the authors fail to cover popular models, such as MiniGPT-4, and QWen-VL.

R: Thank you for pointing out this oversight. We have revised the manuscript to include more models as follows.

“For large vision-language foundation models, CLIP [13], LLaVA [7], MiniGPT-4 [9], MiniGPT-v2 [8], and Qwen-VL [14] have revolutionized the computer vision community.”

[7] H. Liu, C. Li, Q. Wu, and Y. J. Lee, “Visual instruction tuning,” *Advances in Neural Information Processing Systems* 36, 2023.

[8] J. Chen, D. Zhu, X. Shen, X. Li, Z. Liu, P. Zhang, R. Krishnamoorthi, V. Chandra, Y. Xiong, and M. Elhoseiny, “MiniGPT-v2: Large language model as a unified interface for vision-language multi-task learning,” *arXiv preprint arXiv:2310.09478*, 2023.

[9] D. Zhu, J. Chen, X. Shen, X. Li, and M. Elhoseiny, “MiniGPT-4: Enhancing vision-language understanding with advanced large language models,” *arXiv preprint arXiv:2304.10592*, 2023.

[13] A. Radford, J. W. Kim, C. Hallacy, A. Ramesh, G. Goh, S. Agarwal, G. Sastry, A. Askell, P. Mishkin, J. Clark, G. Krueger, and I. Sutskever, “Learning transferable visual models from natural language supervision,” *Proceedings of the 38th International Conference on Machine Learning*, 2021.

[14] J. Bai, S. Bai, S. Yang, S. Wang, S. Tan, P. Wang, J. Lin, C. Zhou, and J. Zhou, “Qwen-VL: A Versatile Vision-Language Model for Understanding, Localization, Text Reading, and Beyond,” *arXiv preprint arXiv:2308.12966*, 2023.

4. In Table I, it's unclear whether the 10,000 images used with GPT-4V are included in those 163,488 images used with GPT-3.5. If included, the second column can be removed.

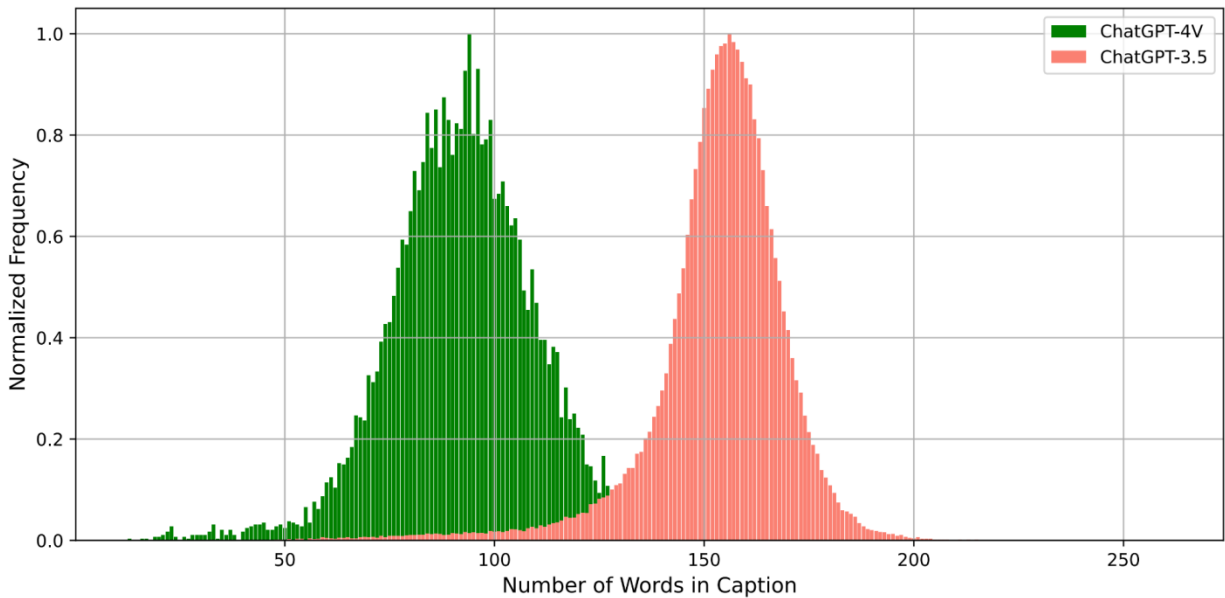
R: Thanks for the insightful comment. The 10,000 images used with ChatGPT-4V are included in those 163,488 images used with GPT-3.5. Following the reviewer's suggestion, we have removed the second column in Table I in the revised manuscript.

Table 1. The number of Sentinel-2 images used for generating captions, along with the corresponding numbers of captions generated by ChatGPT-3.5 and ChatGPT-4V.

Subsets	Number of ChatGPT-3.5 Captions	Number of ChatGPT4-V Captions
Train	98,092	6000
Val	16,348	1000
Test	49,048	3000
Sum	163,488	10,000

5. In Fig. 15, it's better to show the y-axis with probability distribution instead of No. images for a fair comparison between GPT-3.5 and GPT-4.

R: Thanks for the valuable comment. We have revised the Fig. 15 to normalize the frequency for a better visual comparison. Please kindly check it out as follows.



6. Section 3.3 can be compressed.

R: Thank you for the insightful suggestion. We have revised Section 3.3 to make it more concise. Please kindly check out the revised manuscript.

Reviewer #3:

The authors propose an image-text dataset for remote sensing vision-language geo-foundation models. In detail, the image source is from Sentinel-2 data, and the descriptions of land covers is obtained from the semantic segmentation labels of the European Space Agency’s WorldCover project. Moreover, ChatGPT and the manual verification process are introduced to enhance the dataset. The presented work focus on considerable data collection and processing, however the experimentation could be further improved. The reviewer has the following comments:

Main comments:

1. In this work, a global image-text dataset is presented in the field of remote sensing. There are some existing image-text datasets, and the authors are encouraged to specifically compare the proposed dataset with those that exist, such as SkySenseGPT (<https://arxiv.org/pdf/2406.10100>), SkyScript (<https://ojs.aaai.org/index.php/AAAI/article/view/28393>), and RemoteCLIP (<https://ieeexplore.ieee.org/document/10504785>).

R: Thanks for this valuable suggestion. We have added comparisons with the mentioned datasets in Appendix A. Please kindly check out the table as follows.

Table A1. A summary of the remote sensing image-text datasets.

Dataset	#Image-text pairs	Caption Granularity	Caption Generation	Image Data	Geographical Coverage
UCM-Captions (Qu et al., 2016)	10,500	Coarse-grained	Manually Annotated	RGB, UCMerced (Yang and Newsam, 2010)	Regional
Sydney-Captions (Qu et al., 2016)	3,065	Coarse-grained	Manually Annotated	RGB, Sydney (Zhang et al., 2014)	Regional
RSICD (Lu et al., 2017)	54,605	Coarse-grained	Manually Annotated	RGB, Google Earth, Baidu Map	Regional
NWPU-Captions (Cheng et al., 2022)	157,500	Coarse-grained	Manually Annotated	RGB, NWPU-RESISC45 (Cheng et al., 2017)	Regional
RSICap (Hu et al., 2023)	2,585	Fine-grained	Manually Annotated	RGB, DOTA (Xia et al., 2018)	Regional
RSSM (Zhang et al., 2023)	5 M	Coarse-grained	Model-generated & multiple datasets	RGB, multiple datasets	Global
SkyScript (Wang et al., 2024)	2.6 M	Coarse-grained	OpenStreetMap	RGB & multispectral, multiple sensors	Global
FIT-RS (Luo et al., 2024)	1,800,851	Fine-grained	STAR & ChatGPT	RGB, STAR (Li et al., 2024)	Global
RemoteCLIP (Liu et al., 2024)	828,725	Coarse-grained	Rule-based	RGB, multiple datasets	Global
ChatEarthNet	173,488	Fine-grained	WorldCover & ChatGPT	RGB&multispectral, Sentinel-2	Global

Although the number of FIT-RS dataset proposed in the SkySenseGPT paper is greater than that in ChatEarthNet, this work was submitted to arXiv in June 2024, which is four months later than the submission of ChatEarthNet to arXiv in February 2024.

2. For the designed dataset, how to consider the imbalance between foreground and background in the remote sensing segmentation task?

R: Thank you for your question. In our dataset, we use land cover maps to generate detailed descriptions of all land cover types present in the images. As a result, there is no explicit “background” in the sense. Each region in the image is represented by a specific land cover type, as shown in Figs A1, A2, and A3 in Appendix A. Consequently, there is no imbalance issue between foreground and background, as all land cover types are treated equally in the descriptions.

3. The authors are advised to explain the reasons for choosing the land cover maps from WorldCover. In addition, how to measure the accuracy of labelling in these land cover maps?

R: Thanks for the valuable comment. WorldCover is selected for our dataset due to its high accuracy and comprehensive land cover types when compared to other available products. How to measure the accuracy of the global land cover products is challenging. To address this issue, Xu et al. conducted a comparative independent validation of recent 10m global land cover maps. As demonstrated in the study by Xu et al. [1], WorldCover outperforms other alternatives such as Dynamic World [2] and ESRI LULC [3], offering more accurate labels and more land cover types. These factors inspire us to choose WorldCover for constructing our dataset instead of others.

[1] P. Xu, N. E. Tsendbazar, M. Herold, S. de Bruin, M. Koopmans, T. Birch, S. Carter, S. Fritz, M. Lesiv, E. Mazur, A. Pickens, P. Potapov, F. Stolle, A. Tyukavina, R. Van De Kerchove, and D. Zanaga, “Comparative validation of recent 10 m-resolution global land cover maps,” *Remote Sensing of Environment*, 2024.

[2] C. F. Brown, S. P. Brumby, B. Guzder-Williams, T. Birch, S. B. Hyde, J. Mazzariello, W. Czerwinski, V. J. Pasquarella, R. Haertel, S. Ilyushchenko, K. Schwehr, M. Weisse, F. Stolle, C. Hanson, O. Guinan, R. Moore, and A. M. Tait, “Dynamic World, near real-time global 10 m land use land cover mapping,” *Scientific Data*, 2022.

[3] K. Karra, C. Kontgis, Z. Statman-Weil, J. C. Mazzariello, M. Mathis, and S. P. Brumby, “Global land use / land cover with Sentinel 2 and deep learning,” *IEEE International Geoscience and Remote Sensing Symposium*, 2021.

4. The authors mentioned that the proposed dataset has many high-quality and detailed descriptions, and is it validated by quantitative comparison experiments with other datasets?

R: We appreciate the reviewer’s comment on this point. We provided a table to compare the proposed dataset with existing ones as follows.

Table A1. A summary of the remote sensing image-text datasets.

Dataset	#Image-text pairs	Caption Granularity	Caption Generation	Image Data	Geographical Coverage
UCM-Captions (Qu et al., 2016)	10,500	Coarse-grained	Manually Annotated	RGB, UCMerced (Yang and Newsam, 2010)	Regional
Sydney-Captions (Qu et al., 2016)	3,065	Coarse-grained	Manually Annotated	RGB, Sydney (Zhang et al., 2014)	Regional
RSICD (Lu et al., 2017)	54,605	Coarse-grained	Manually Annotated	RGB, Google Earth, Baidu Map	Regional
NWPU-Captions (Cheng et al., 2022)	157,500	Coarse-grained	Manually Annotated	RGB, NWPU-RESISC45 (Cheng et al., 2017)	Regional
RSICap (Hu et al., 2023)	2,585	Fine-grained	Manually Annotated	RGB, DOTA (Xia et al., 2018)	Regional
RS5M (Zhang et al., 2023)	5 M	Coarse-grained	Model-generated & multiple datasets	RGB, multiple datasets	Global
SkyScript (Wang et al., 2024)	2.6 M	Coarse-grained	OpenStreetMap	RGB & multispectral, multiple sensors	Global
FIT-RS (Luo et al., 2024)	1,800,851	Fine-grained	STAR & ChatGPT	RGB, STAR (Li et al., 2024)	Global
RemoteCLIP (Liu et al., 2024)	828,725	Coarse-grained	Rule-based	RGB, multiple datasets	Global
ChatEarthNet	173,488	Fine-grained	WorldCover & ChatGPT	RGB&multispectral, Sentinel-2	Global

We also conduct experiments to evaluate widely established multimodal large language models (MLLMs). Specifically, we evaluate several MLLMs, including LLaVA [4], MiniGPT-v2 [5], MiniGPT-4 [6], and GeoChat [7]. These evaluations further support our conclusion that ChatEarthNet is a valuable resource for training and evaluating vision-language geo-foundation models for remote sensing. Please kindly check out the revised version as follows.

“To demonstrate the effectiveness of ChatEarthNet in evaluating multimodal large language models, we conduct benchmarking experiments using a range of existing models. Given that ChatEarthNet includes long and detailed descriptions, it is not well-suited for evaluating CLIP-based vision-language models like RemoteCLIP [8] and RS-CLIP [9]. Therefore, we focus on evaluating widely used multimodal large language models, including LLaVA-v1.5 [4], MiniGPT-v2 [5], MiniGPT-4 [6], and GeoChat [7]. All experiments are performed using the ChatGPT-4V version of our dataset, which allows us to conduct extensive evaluations across multiple models while significantly reducing computational resource requirements.

Table 2 summarizes the results of these evaluations, detailing the models’ performance across several widely used metrics: BLEU, CIDEr, METEOR, ROUGE-L, and SPICE. We evaluate these models in two experimental settings. The first is a zero-shot transfer setting, where pre-trained models are used to generate captions without any additional training or fine-tuning on the ChatEarthNet dataset. The first four rows in Table 2 present the results of this zero-shot transfer setting. The performance is suboptimal due to the domain gap between the models’ original training datasets and our test dataset. In addition to zero-shot testing, we fine-tune some of these models on the ChatEarthNet dataset (ChatGPT-4V version) and report their performance. The results clearly show that fine-tuning on our proposed dataset significantly improves image captioning performance in the context of remote sensing data. These findings strongly suggest that ChatEarthNet is a valuable resource for both training and evaluating vision-language geo-foundation models in the remote sensing domain.”

Table 2. Performance comparison of different models on the ChatEarthNet (ChatGPT-4V Version) test set.

Models	Bleu-1	Bleu-2	Bleu-3	Bleu-4	CIDEr	METEOR	ROUGE_L	SPICE
LLaVA-v1.5	0.285	0.116	0.040	0.014	0.012	0.104	0.186	0.093
MiniGPT-v2	0.279	0.116	0.041	0.015	0.009	0.104	0.180	0.091
MiniGPT-4	0.175	0.072	0.023	0.008	0.000	0.116	0.180	0.079
GeoChat	0.199	0.088	0.034	0.011	0.005	0.067	0.126	0.083
MiniGPT-4 (ChatEarthNet)	0.310	0.184	0.113	0.071	0.001	0.209	0.254	0.186
GeoChat (ChatEarthNet)	0.445	0.269	0.170	0.109	0.094	0.208	0.286	0.211

[4] H. Liu, C. Li, Q. Wu, and Y. J. Lee, “Visual instruction tuning,” *Advances in Neural Information Processing Systems* 36, 2023.

[5] J. Chen, D. Zhu, X. Shen, X. Li, Z. Liu, P. Zhang, R. Krishnamoorthi, V. Chandra, Y. Xiong, and M. Elhoseiny, “MiniGPT-v2: Large language model as a unified interface for vision-language multi-task learning,” *arXiv preprint arXiv:2310.09478*, 2023.

[6] D. Zhu, J. Chen, X. Shen, X. Li, and M. Elhoseiny, “MiniGPT-4: Enhancing vision-language understanding with advanced large language models,” *arXiv preprint arXiv:2304.10592*, 2023.

[7] K. Kuckreja, M. S. Danish, M. Naseer, A. Das, S. Khan, and F. S. Khan, “Geochat: Grounded large vision-language model for remote sensing,” *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*, 2024.

[8] F. Liu, D. Chen, Z. Guan, X. Zhou, J. Zhu, Q. Ye, L. Fu, and J. Zhou, “RemoteCLIP: A vision language foundation model for remote sensing,” *IEEE Transactions on Geoscience and Remote Sensing*, 2024.

[9] X. Li, C. Wen, Y. Hu, and N. Zhou, “RS-CLIP: Zero shot remote sensing scene classification via contrastive vision-language supervision,” *International Journal of Applied Earth Observation and Geoinformation*, 2023.

5. The authors are encouraged to discuss which attributes are more important for the multimodal vision-language learning than for the vision representation, e.g., relative size or relative position described in the text.

R: Thanks for the insightful comment. In multimodal vision-language learning, attributes like relative size and relative position are important because they provide contextual information that bridges the gap between visual data and natural language. While vision-only representations are good at capturing visual features such as color, texture, and shape, they may fall short in conveying spatial relationships and comparative attributes inherent in complex scenes like satellite imagery. For instance, understanding that “a small lake is nestled beside a large forest” requires integrating both visual cues and linguistic descriptions to fully comprehend the scene.

ChatEarthNet emphasizes these attributes in the generated descriptions. By employing detailed prompts and leveraging semantic segmentation labels from the WorldCover project, we ensure that the natural language descriptions include rich details about relative sizes and positions. This enriches the dataset, making it more suitable for training models that need to understand and generate descriptions involving spatial relationships and comparative sizes.

We believe that highlighting these attributes enhances the performance of multimodal models in tasks such as image captioning, scene understanding, and geospatial analysis. It allows models to develop a more comprehensive understanding of the scene by aligning visual features with corresponding textual descriptions that capture both absolute and relative attributes. In contrast to vision-only models, which might detect objects without understanding their spatial relationships, multimodal models can interpret and describe how different elements in an image relate to one another, leading to more informative and accurate outputs.

We appreciate the reviewer’s insightful comment. However, this manuscript mainly focuses on the construction and analysis of the dataset. In the future work, we plan to conduct experiments to quantify the impact of these attributes on model performance.

6. It seems that there is a lot of textual information described in the proposed dataset, does this introduce interfering information? How to avoid negative learning due to interfering information?

R: Thank you for your insightful comment. We acknowledge that incorporating extensive textual information can introduce challenges, such as noise or irrelevant details that might negatively impact model training. However, with careful prompt design and semantic guidance, we can mitigate these concerns, ensuring that the dataset enhances learning rather than hinders it.

We utilize detailed and carefully designed prompts to guide ChatGPT in generating descriptions that are both informative and relevant, avoiding inaccuracies, redundancies, or irrelevant details that could introduce noise. For example, we only focus on three main land cover types in Algorithm 1 instead of all land cover types. Moreover, by incorporating semantic segmentation labels from the WorldCover project, we ensure that the descriptions focus on land cover types and spatial relationships in the image. This semantic guidance helps filter out irrelevant information and emphasizes attributes that are crucial for understanding and interpreting remote sensing data.

From the perspective of dataset construction, we have implemented several strategies to enhance quality. However, mitigating negative learning mainly depends on model design, which is beyond the scope of this paper focusing on introducing the dataset. Nevertheless, we believe this is a valuable research direction and intend to pursue it in our future work.

Minors

1. Please rephrase the description of “Image-Text Dataset”, could the proposed dataset be used with other vision-language tasks, such as, image-to-text and text-to-image synthesis?

R: Thank you for your valuable comment and question. Yes, the ChatEarthNet dataset can indeed be readily used for other generative tasks, such as image-to-text and text-to-image synthesis. In addition, the dataset can also be easily extended to visual question answering by leveraging the capabilities of current large language models.

This versatility is why we refer to it as an “image-text dataset,” a high-level term that captures its potential for a range of tasks. We have added further clarification in the revised manuscript as follows:

“It is worth noting that the proposed ChatEarthNet dataset can be readily used for other tasks, including image-to-text and text-to-image synthesis. Moreover, leveraging the capabilities of large language models, it can also be extended to visual question answering by prompting large language models for questions and answers based on rich descriptions. This versatility enhances the dataset’s value to the community.”

2. The “2.5 Manual verification” section is suggested to add details of manual adjustments, such as under what circumstances manual verification are required and what information is adjusted. An example is visual representation.

R: Thank you for your valuable suggestion. We have added more details to section “2.5 Manual verification” to better present the manual adjustment process. Please kindly check out the revised version as follows.

“To avoid unexpected descriptions on comparisons between different images, we design prompts like “Generate the four descriptions separately; do not add connections between them” to guide the description generation process. Despite providing specific instructions for ChatGPT-4V to treat each image individually, it occasionally make mistakes by describing comparisons between images. For instance, phrases such as “similar to other images” and “compared with previous images,” need to be revised to eliminate comparisons. We therefore manually check all captions and refine comparison-related captions.”

During the manual verification process, the old captions are overwritten, making it impossible to retrieve the precise before-and-after states for comparison. However, to illustrate the general concept, we can provide a hypothetical example that demonstrates the essence of the process:

Original description: “The fourth image features a noticeable spread of developed areas, with a larger extent than in the other images, especially strong in the top left and middle regions, indicative of a significant human footprint. Grassland areas are uniformly distributed throughout, suggesting a balance between natural landscapes and developed spaces. Crops are situated in the lower quadrants, forming large agricultural plots. Similarly, the depiction of this landscape suggests a balance between urban development and agricultural uses with some remaining grassland regions.”

Corrected description: “This image features a noticeable spread of developed areas, especially strong in the top left and middle regions, indicative of a significant human footprint. Grassland areas are uniformly distributed throughout, suggesting a balance between natural landscapes and developed spaces. Crops are situated in the lower quadrants, forming large agricultural plots. The depiction of this landscape suggests a balance between urban development and agricultural uses with some remaining grassland regions.”

In this example, “The fourth image” changes to “This image,” “with a larger extent than in the other images,” is removed, and “Similarly,” is removed. This shows how the manual verification process is done by removing comparative elements. We hope this example helps clarify the manual verification process.

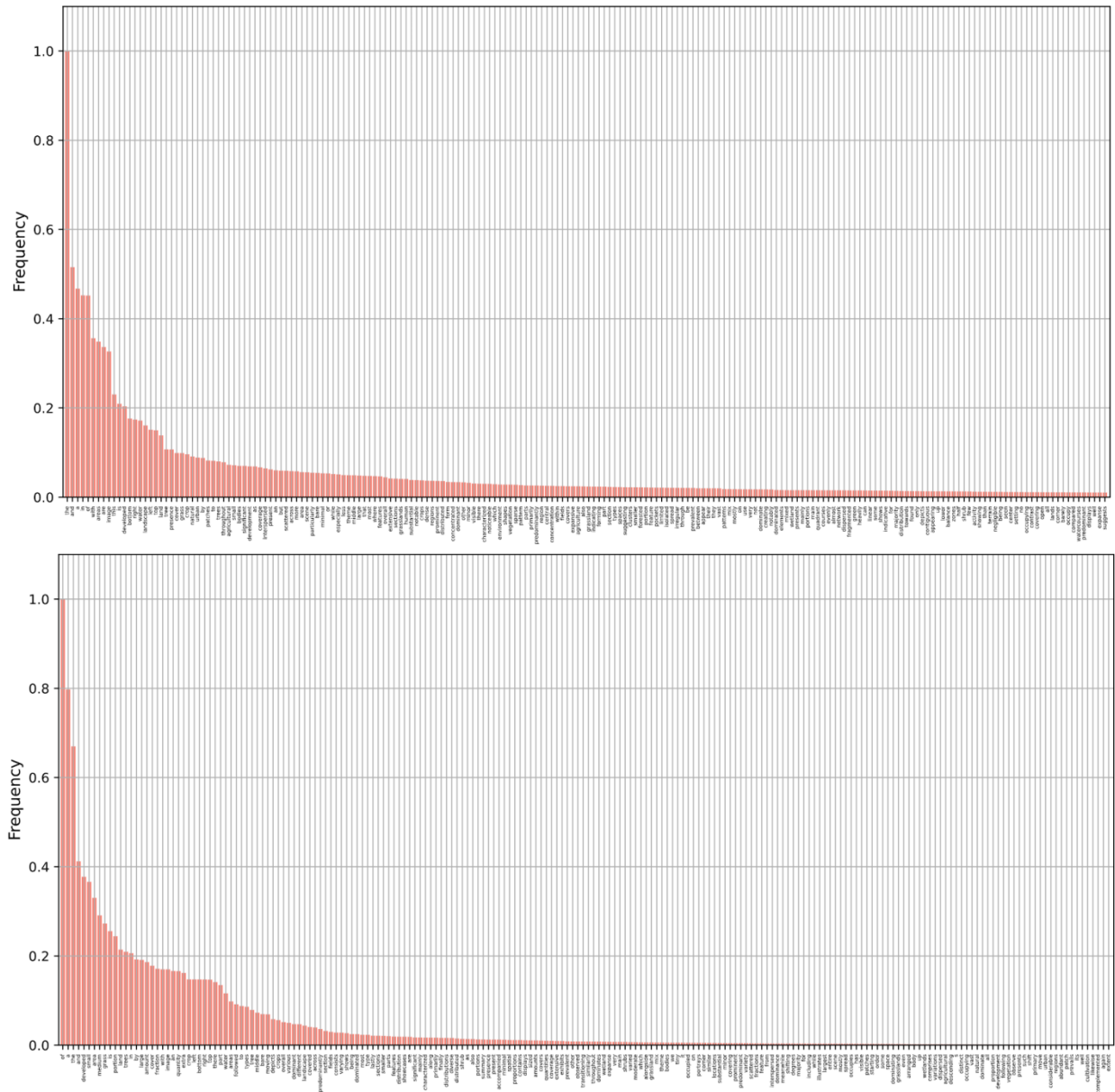
3. The y-axis of Figs. 9-10 are suggested to be revised to the same to make contrasts clearer.

R: Thank you for your valuable suggestion. We agree that using the same y-axis scale for both figures could make comparisons clearer. However, there are some considerations to keep in mind.

If we adjust the y-axis to the maximum frequency value of 2,000,000 for both figures, the plot for ChatGPT-4V will become difficult to interpret due to its significantly lower

frequency numbers. Alternatively, normalizing the frequency to a range of 0 to 1, as shown below, results in plots that are visually identical to Figs. 9-10 in the manuscript. However, Figs. 9-10 provide more insight into the actual number of samples in the two subsets by retaining the true value range of the frequencies.

While we appreciate the reviewer’s suggestion, we believe that preserving the original y-axis scale provides more meaningful information and would prefer to retain the current version.



4. The authors claim that “it stands out as the first dataset offering high-quality detailed land cover descriptions on a global scale” on line 230 of page 14. Please replace this expression with a more accurate description.

R: Thank you for pointing out this. We have revised this sentence as follows:

“In terms of the number of image-text pairs, the ChatEarthNet dataset is not the largest dataset available, but it offers high-quality detailed land cover descriptions on a global scale.”

5. Page 10 has gaps, and the authors are encouraged to reformat the article.

R: Thank you for the insightful suggestion. We have addressed the gaps in the layout. Please kindly check out the revised version.