Thank you for taking the time to read our manuscript and provide constructive feedback. These comments were helpful for improving the paper. Please find our point-by-point responses to specific comments below. Reviewer comments are in black, followed by our responses in blue. Underlined portions indicate changes that were made in the manuscript. Line numbers refer to the revised manuscript.

Response to RC2: 'Comment on gmd-2023-143', Anonymous Referee #2, 13 Oct 2023

Comment 1: *My biggest issue is with my lack of understanding of the chlorophyll retrieval itself (how it is calculated and/or how the weights are used) and of its performance and validation.*
Response: This is valuable feedback, thank you. We have tried to clarify this throughout the manuscript —please refer to our responses to your comments below.

Importantly, we have modified the manuscript to provide additional clarity for the reader about how chlorophyll is 'retrieved' (i.e., calculated) in ChlOSP:

(Line 160) "To calculate the weight from modeled sea ice and cloud cover fields, which are both expressed in terms of the fraction of a grid cell that is covered, these values are subtracted from 1. All weights are assumed to be independent from one another, so the final weight is the product of the weights calculated from each input parameter. At every model time step, the surface chlorophyll is multiplied by the weights. Then, the weighted chlorophyll and the weights are both output by the model at the frequency specified by the user when running CESM (i.e. hourly, monthly, etc.). Both outputs are needed to calculate the weighted mean over space and/or time. The weighted chlorophyll is not a physical value that should be analyzed independently from the weights. When calculating the weighted mean of chlorophyll, the weighted chlorophyll output corresponds to the numerator and the weights output corresponds to the denominator in Equation 1:"

$$\text{weighted mean} = \frac{\sum_{i=1}^{n} w_i X_i}{\sum_{i=1}^{n} w_i}$$

To the reviewer's point about performance and validation, we focus our paper on a description of ChlOSP development, and we provide a validation of this development in the context of missing data. Figure 11 illustrates that the long-term mean modeled chlorophyll can differ quite a bit from that observed by satellite. We have a second study in the works with ChlOSP that will provide a detailed comparison of ChlOSP-generated chlorophyll and satellite chlorophyll across a wide range of spatial and temporal scales for the MODIS satellite period.

Comment 2: *I also left wondering about how the results would look if shorter time scales were considered (from daily to monthly to annually). For the most part, decadal averages are presented. This paints a great average picture, but shorter time scales are important too,* *particularly regarding some of the applications of ChlOSP presented by the Authors. It would be appreciated if they add a quick case study on shorter time scales.*

Response: We appreciate the suggestion to look at shorter time scales. We have intentionally looked at longer time scales to account for the mismatch in the timing of interannual variability between the coupled model and the real world. When validating Earth system models, it is common to look at chlorophyll in terms of multi-year means when comparing to observations. We agree that shorter time scales would be important for applications, especially gap-filling, which will be addressed in a future paper. We have added a sentence in the abstract clarifying the goals of this paper (line 7): "Here, we introduce this new tool and present a preliminary study focusing on long timescales."

Comment 3: *Line 29: Since Hu uses a line-height approach, you might mention this in addition to just the blue-to-green ratio.*

Response: Thank you. We added a clarifying statement to this sentence (line 28): "The most commonly used algorithms to derive chlorophyll concentration from remote sensing reflectance rely primarily on the ratio of blue to green wavelengths."

Comment 4: *Line 139: The satellite "sees" a vertically optically weighted chlorophyll signal, not a sum of chlorophyll layers. Consider commenting on the difference between the remotely sensed signal and the sum that you use. Note also that in some waters, the satellite will not see 10 m deep in some (blue) wavelengths used in the retrieval algorithm.*

Response: Thank you for this comment. We have added a couple sentences addressing this in the introduction, where we discuss the differences between remotely sensed and modeled chlorophyll (line 55): "Satellite observations represent a vertically optically weighted chlorophyll signal, which is generally limited to the near-surface ocean due to light attenuation at depth. Therefore, the comparison with the vertically resolved model output is limited to the surface layer."

We also mention this assumption again in our description of ChlOSP (line 141): "We assume that the satellite can only see the surface layer of the POP2 grid, which represents depths from 0 to 10 meters. Although the depth seen by a satellite depends on the optical constituents present in the water column, the surface layer of the model roughly aligns with depths of in situ measurements used to validate the SeaWiFs chlorophyll retrievals (Gregg et al. 2004). The chlorophyll concentration in each surface model grid cell is calculated as the sum of chlorophyll from each phytoplankton functional group represented in MARBL."

Comment 5: *Lines 135 and 141: "missing" and "viewable" refers to present and absence of clouds, etc.? Suggest clarifying in both places.*

Response: Thank you for this suggestion. We have added clarification that "viewable" means that the surface ocean is not obscured by clouds, sea ice, or low solar angles (line 147): "At each model time step, POP2 uses multiple variables to calculate the chlorophyll weights, which represent the fraction of each model grid cell that would be viewable by a satellite (i.e., the fraction of the surface area that is not obscured)." In this way, "missing data" refers to those grid cells obscured by clouds, sea ice, and low solar angles.

Comment 6: *Line 144: Suggest changing to "prevent satellite detection using passive instruments".*
Response: Agreed, we have updated this sentence: "ChlOSP accounts for clouds, sea ice, and low sunlight (high solar zenith angle), all of which prevent satellite detection using passive instruments."

Comment 7: *Line 150: Change to "Level 3 ocean color retrievals have a high spatial resolution".*
Response: Changed to "Satellite-derived level 3 ocean color products have a high spatial resolution" since it may not be obvious that Level 3 refers to satellite data.

Comment 8: *Line 155: I don't understand as written why you'd multiply the surface chl by the weights. I get that you're deriving a fraction of viewable area in each 1-deg model cell that represents how much of that cell MODIS would see (0.5 indicating 50% of the 1-deg cell would be visible to MODIS). Right? But, applying that weight to the chl value would artificially lower the chl value, no? As an example, if you're 1-deg cell has a chl value of 1.0 mg/m3 and that cell in reality is completely homogeneous, then even if half the cell was not viewable by MODIS, the satellite pixels would still have values of 1.0 mg/m3. But, multiplying by 0.5 would lower the value to 0.5 mg/m3. I have no doubt that I'm missing something, so please elaborate in this section.*
Response: We apologize for the confusion and are grateful that you brought this to our attention. We have clarified how the weights are calculated by including an equation along with several additional explanatory sentences in this paragraph:

"To calculate the weight from modeled sea ice and cloud cover fields, which are both expressed in terms of the fraction of a grid cell that is covered, these values are subtracted from 1. All weights are assumed to be independent from one another, so the final weight is the product of the weights calculated from each input parameter. At every model time step, the surface chlorophyll is multiplied by the weights. Then, the weighted chlorophyll and the weights are both output by the model at the frequency specified by the user when running CESM (i.e. hourly, monthly, etc.). Both outputs are needed to calculate the weighted mean over space and/or time. The weighted chlorophyll is not a physical value that should be analyzed independently from the weights. When calculating the weighted mean of chlorophyll, the weighted chlorophyll output corresponds to the numerator and the weights output corresponds to the denominator in Equation 1:"

$$\text{weighted mean} = \frac{\sum_{i=1}^{n} w_i X_i}{\sum_{i=1}^{n} w_i}$$

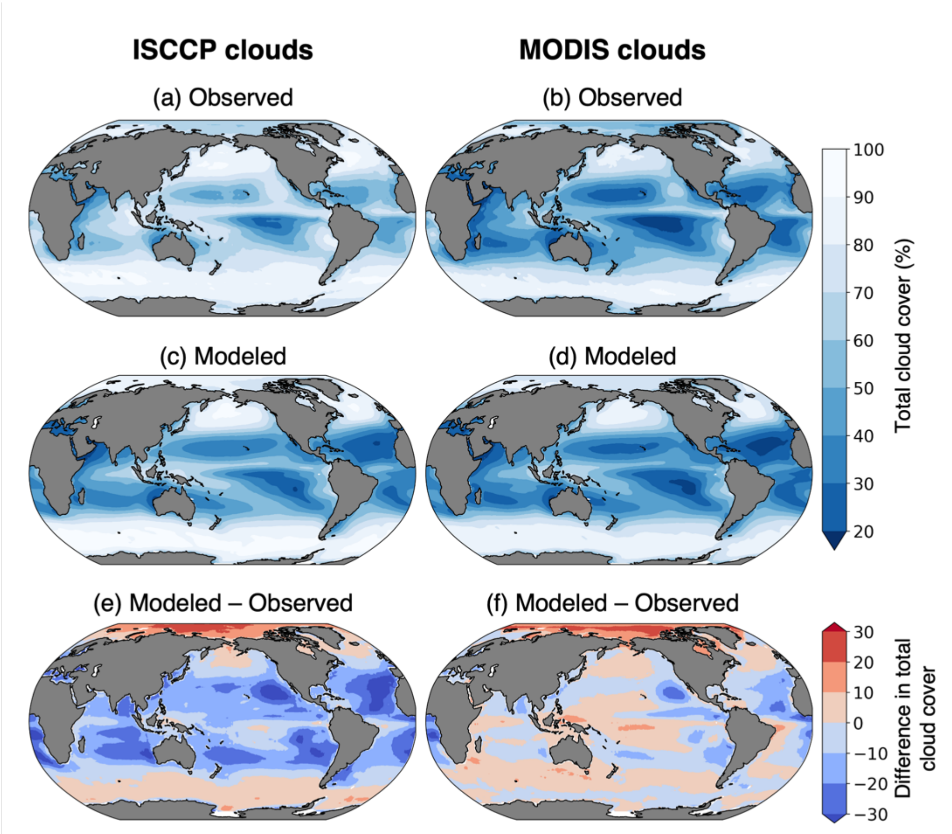
Comment 9: *Line 156: What does "desired frequency" mean?*
Response: Changed to "Then, the weighted chlorophyll and the weights are both output by the model at the frequency specified by the user when running CESM (i.e. hourly, monthly, etc.)."

Comment 10: *Line 203: Sorry if I missed it, but I think this is the first time you mention "time-average". Please elaborate.*

Response: We clarified the language here. The paragraph now reads: "When calculating the global mean of chlorophyll, we weight each grid cell by how frequently it was sampled (Equation B3). To do this, we calculate the time-mean of the weights, then multiply this by the area of each grid cell, which effectively represents the sample size for each grid point. Figure S3 shows the chlorophyll climatologies along with the corresponding time-mean of the weights for each cloudy configuration. The normalized weights represent the mean area seen by the satellite relative to other points on the globe."

Comment 11: *Figure 3: Suggested adding a 3rd row that presents a difference map.*

Response: Thank you for this suggestion. We have added a 3rd row to this figure.



Comment 12: *Line 230: Please identify from where these data were acquired.*

Response: We now include the link to OC-CCI data products, which is where we acquired the data (line 243): "...we use a merged chlorophyll product that combines several polar-orbiting sensors to increase daily data coverage: the Ocean-Colour Climate Change Initiative (OC-CCI, https://www.oceancolour.org/) dataset, version 6.0."

Comment 13: *Line 242: Mentioning sun glint is important, thank you. Consider elaborating on how omitting sun glint in this study might influence your results. Given that sun glint is regional, I would expect meaningful impacts at low latitudes. In practice for the future, you'd have to stratify your interpretation of results by sensor – SeaWiFS, e.g., tilts and saw far less sun glint than MODIS, which has complicated their intercomparison.*
Response: We added an additional sentence about sun glint and inter-orbit gaps impacting low latitudes. We cite the findings from Gregg & Casey 2007, which indicate that these factors do not play a significant role in chlorophyll biases in these regions. However, it could be interesting to test this with ChlOSP in a future study. As you mention, this would involve adding different model outputs for different sensors, so this may involve significant effort.

We have added this sentence at line 256: "Sun glint and inter-orbit gaps mainly impact low to mid-latitude regions. However, Gregg et al. 2004 found that chlorophyll sampling biases in these regions are small, so addressing these issues was not the primary goal of ChlOSP."

Comment 14: *Section 2.4: I appreciate the careful evaluations presented, but I was surprised that direct-ish comparisons of satellite-derived and ChlOSP-derived chlorophyll were not presented. More specifically, I don't see much in the way of a performance assessment of the ChlOSP chlorophyll retrievals. Is there a reason for this? Fig 11 touches on this, but in a highly averaged (20+ years) way that doesn't really validate the ChlOSP chlorophyll retrieval. Could some short-term temporal subset of model output be resampled in a way using distributions of valid MODIS retrievals to create map(s) that enable a semi-direct comparison of chl in common bins? I realize that it won't be perfect (pre-industrial average vs. modern day MODIS), but at least seeing maps and their differences would provide the reader some knowledge of the scale of differences between the two chl retrievals. Overall, I guess what I'm asking is, is there more than can be done to convince a reader that the ChlOSP chlorophyll retrievals are validated?*
Response: Thank you for this comment. We agree that comparison with real-world chlorophyll is important for CESM model validation — enabling this type of comparison was partly our motivation for developing ChlOSP. We focus our paper on a description of ChlOSP development, and we provide a validation of this development in the context of missing data. Indeed, Figure 11 illustrates that the long-term mean modeled chlorophyll can differ quite a bit from that observed by satellite. We have a second study in the works with ChlOSP that will provide a detailed comparison of ChlOSP-generated chlorophyll and satellite chlorophyll across a wide range of spatial and temporal scales for the MODIS satellite period.

Comment 15: *Line 278: Not obvious to me how Figure 6 shows anything "temporal". Would "long-term mean" be more appropriate wording?*
Response: We have changed "temporal" to "long-term" mean: "A comparison of the Standard, Clear-Sky, and Cloudy (ISCCP) chlorophyll climatologies reveals that the long-term mean is impacted by missing data (Fig. 6)"

Comment 16: *Table 2: Might be informative to expand this table to include specific basins or regions?*

Response: Yes, thank you. We have added a supplemental table with this information. The table is referenced in line 324: "Global mean chlorophyll concentration estimated by the Cloudy ChlOSP output is ~20 % different from that estimated by the Standard configuration (Table 1; differences for individual biomes included in Table S1)."

Biome	Standard	Clear-Sky	Clear-Sky Swath	Cloudy: ISCCP	Cloudy: MODIS	Cloudy: MODIS Swath
1	0.511	205.2%	139.0%	208.3%	204.5%	147.1%
2	0.770	40.3%	18.2%	16.7%	19.8%	5.7%
3	0.349	11.4%	1.7%	-13.0%	-10.1%	-14.7%
4	0.100	-2.3%	0.4%	-8.6%	-8.1%	-6.0%
5	0.097	-3.2%	-1.6%	0.1%	-0.6%	0.5%
6	0.356	-5.1%	-5.5%	-0.1%	-2.8%	-2.7%
7	0.089	0.4%	1.5%	-9.6%	-8.8%	-7.6%
8	0.357	141.9%	125.4%	99.1%	107.7%	90.0%
9	0.644	73.7%	53.5%	68.1%	69.6%	54.6%
10	0.454	17.5%	2.4%	0.9%	2.1%	-5.8%
11	0.109	-2.9%	-1.0%	-4.9%	-5.7%	-4.0%
12	0.145	-6.5%	-6.5%	-0.4%	-1.7%	-2.5%
13	0.141	-1.8%	-1.9%	-5.8%	-6.4%	-6.4%
14	0.112	-2.7%	-2.2%	-5.6%	-5.6%	-4.9%
15	0.342	23.2%	3.4%	29.3%	27.3%	11.5%
16	0.220	59.1%	32.0%	92.7%	77.4%	49.4%
17	0.148	162.2%	134.8%	244.7%	206.4%	179.7%

Table S1. Mean chlorophyll values within ocean biomes (Figure S4), calculated using Equation B3. Column values are reported as percent difference relative to Standard.

Comment 17: *Line 318: Re: "the regions that show" – maybe a map of sample sizes would be useful?*

Response: We agree with this thought, but we think that this has already been sufficiently shown. Figure S3 shows the normalized weights, which conveys similar information. We have added a reference to that figure here: "The regions that show some of the highest sampling biases, such as subpolar biomes, are sampled very infrequently due to cloud cover or lack of sunlight (Fig. S3)." Additionally, Figure 4 shows the percentage of days with data, which indicates the sample size as well.