Review of Impact of grids and dynamical cores in CESM2.2 on the surface mass balance of the Greenland Ice Sheet

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Summary
The manuscript describes a series of simulations with the CESM2.2 earth system model under different grid configurations and the impact of these configurations on simulated Greenland ice sheet (GrIS) mass balance. Specifically, the authors employ two standard longitude-latitude configurations, along with a cubed-sphere grid with a spectral element (SE) dycore. The SE simulations include an option for regional grid refinement, for which this manuscript provides the first documentation. Model results are compared with high resolution reanalysis-forced regional climate model simulations from the Regional Atmospheric Climate Model (RACMO2.1), satellite-derived cloud products, and the ERA5 reanalysis. The results indicate that the SE cubed-sphere simulations degrade model performance over the GrIS, resulting in overestimated precipitation and runoff. This is likely due to the locally higher resolution over the GrIS in the longitude-latitude grid configuration. Regional grid refinement improves simulated SMB terms, particularly precipitation, and tends to reverse an arctic cold bias in the model. The highest level of refinement results in too-warm temperatures over the GrIS leading to overestimated melt in that simulation.

General Comments
The manuscript is well-written and provides an important contribution to understanding simulation of ice sheet SMB in global climate model simulations. The paper provides important documentation of the impact of changes to the grid and spatial resolution in CESM on ice sheet SMB. Some points below should be addressed before the manuscript is published but I feel these are minor overall.

One general comment: surface albedo has been shown to be an important factor in climate model simulations of GrIS SMB (e.g. van Angelen et al., 2012; Cullather et al., 2014; Helsen et al., 2017; Alexander et al., 2019), but this has not been discussed by the authors. Some of the melt differences could be influenced by the interaction between precipitation, surface albedo, and melt. In areas of underestimated snowfall, which tend to occur along the ice sheet margins, erroneous bare ice exposure can lead to a darker surface and enhanced melt. IThe authors should examine the possibility of differences in albedo influencing simulated melt.

Cullather, R. I., Nowicki, S. M. J., Zhao, B., & Suarez, M. J. (2014) Evaluation of the surface representation of the Greenland Ice Sheet in a General Circulation Model. *J. Climate*, 27 (13), 4835-4856.

Helsen, M. M., van de Wal, R. S. W., Reerink, T. S., Bitanja, R., Madsen, M. S., Yang, S., Li, Q., & Zhang, Q. (2017) On the importance of the albedo parameterization for the mass balance of the Greenland ice sheet in EC-Earth. *The Cryosphere*, 11, 1949-2017.

Alexander, P. M., LeGrande, A. N., Fischer, E., Tedesco, M., Fettweis, X., Kelley, M., Nowicki, S. M. J., & Schmidt, G. A. (2019) Simulated Greenland surface mass balance in the GISS ModelE2 GCM: Role of the ice sheet surface. *J. Geophys. Res.,* 124 (3), 750-765.

Specific Comments

1. **Lines 19-24:** The language is confusing here. The quasi-uniform grids should be introduced with a brief description of how they are constructed, and what “quasi-uniform” means. Then their performance in terms of surface mass balance can be discussed, followed by the impact of grid refinement on the simulation. Also perhaps it can be mentioned here how one dycore is linked to two lon-lat configurations and another is linked to the quasi-uniform unstructured grid.
2. **Line 38:** Again, please explain the meaning of “quasi-uniform unstructured grid”
3. **Lines 52-55:** Again, it would be helpful if “globally uniform unstructured grid”, “dynamical cores”, and “variable-resolution grids” can be briefly explained. Additionally, perhaps it should be explained here that two dycores are examined, one linked to the longitude latitude grid, and the other linked to unstructured grids.
4. **Line 94:** Why is “conversely” used here? It seems like a word such as “Additionally” would be more appropriate.
5. **Lines 115-116:** Clarify that this is a positive precipitation bias in the interior.
6. **Lines 111-123:** Here there is no mention of elevation classes. I suggest mentioning them briefly here as this is a way to increase SMB resolution (from the standpoint of runoff but not precipitation) that is used in CESM.
7. **Figure 1, caption:** Please provide a brief description of each of the grids here for the benefit of the reader. E.g. (a) 2° latitude-longitude grid (f19), etc.
8. **Line 189:** Briefly explain “cubed-sphere”.
9. **Table 1:** It would be helpful to specify which grids are latitude-longitude and which are unstructured either as a column in the table or text in the caption.
10. **Lines 229-230:** Does ne30 indicate 30 quadrilateral elements per face and pg3 indicate 3 control volumes per element? Please clarify.
11. **Lines 239-243:** I suppose degree coordinates here correspond the latitude dimension, or degrees at the equator. Please clarify.
12. **Line 249:** This is the first time RACMO is mentioned. Please explain briefly what RACMO is here.
13. **Line 254:** Clarify that “expensive” means “computationally expensive.”
14. **Line 301:** Though not essential it would be interesting to know the lapse rate that is assumed.
15. **Line 314:** I’m confused as to why accumulation below 10 m does not contribute to SMB. How is this addition of mass accounted for?
16. **Lines 318-319:** What is the period for the prescribed SSTs?
17. **Lines 322-338:** This section only includes discussion of RACMO and in-situ measurements, which are not used, while ERA5, CERES and CALIPSO are not at all discussed. These validation products must be documented here as well.

18. **Line 322:** RACMO2 is still a model, and does not fall under an "observational" dataset. I suggest changing this to read "Validation Datasets", "Evaluation Datasets" or "Comparison Datasets".
19. **Figure 3 caption:** I believe the left and right figures are switched here. Also, the fact that RACMO RCM simulations are included should be mentioned.
20. **Formula 1:** The f's in runoff seem to have been turned into function symbols. Also I suggest using "evaporation + sublimation" to avoid confusion with division.
21. **Line 406:** I believe this should read "expressed as temperature differences".
22. **Lines 408-416, 429-433:** How can the effect be primarily ascribed to condensational heating if the temperature differences do not align in magnitude or spatial extent? Are there feedbacks involved? Please clarify in the text, or qualify the statements.
23. **Lines 437-438:** This also seems to be true in other cases.
24. **Lines 440-441:** This seems consistent with other results that increasing resolution led to a temperature increase.
25. **Line 459:** Perhaps the authors could mention the potential influence of clouds earlier as prior to this point, they are not mentioned.
26. **Line 479:** Clarify that cooler temperatures in the coarse resolution simulations are being referred to here.
27. **Figure 8:** The CALIPSO grid appears to be coarser resolution than the CERES grid. Is this a 2° grid?
28. **Lines 573-575:** Wouldn't the elevation class scheme fix this problem by raising the ice-covered sub-grid portion to a higher elevation?
29. **Lines 606-616:** If the biases are larger at low elevations, it could also be coincidental that these areas also have lower ice fractions. I think the authors should also consider the possibility of other factors.
30. **Lines 675-680:** Perhaps the fact that clouds and precipitation move more easily inland could reduce snowfall and increase shortwave radiation along the coast, enhancing melt.
31. **Lines 681-688:** Again, I'm curious about the impact of elevation classes and whether precipitation-albedo feedbacks could influence the melt biases. I suppose the elevation classes might not entirely balance out other coarse-resolution effects.
32. **Line 719:** Change "spectra-element" to "spectral-element".
33. **Line 729:** g can be defined after mentioning T_1 for clarity.
34. **Line 731:** Add "is the" before "surface geopotential".
35. **Equation A5:** How is $T^{(ref)}$ computed?
36. **Lines 740-748:** Here some terms should be defined, including T_v, θ_v and p_0.