Ocean Phytoplankton Biogeography: Earth System Model Estimates at Coarse and Fine Resolution

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Introduction

In the ocean, phytoplankton serve as the base of the oceanic food web and, through photosynthesis, draw down CO_2 from the atmosphere and fix the inorganic carbon into organic matter. The community dynamics of different groups of phytoplankton can give us insight into the changing conditions of our planet. We can simulate these changes with Earth System Models. As technology progresses, these models are becoming increasingly precise tools for predicting the future.

Knowing which model resolution is the most accurate is key for determining were time and money should be spent when analyzing phytoplankton biogeography, as finer resolution models come at an extremely high computational cost. Here we compare the biogeography of diatoms and small phytoplankton in the Southern Ocean at coarse (1°x 1°) and fine (0.1°x 0.1°) horizontal resolution. We aim to investigate the differences in phytoplankton abundance and species distribution across these two resolutions.

Methods: Averaging and Interpolating

- We analyzed diatom and small phytoplankton carbon concentration from the coarse and fine resolution model configurations.
- Annual-mean phytoplankton carbon averaged over the full simulation period for both configurations were compared.
- The averaged fine resolution output was interpolated to the coarse resolution grid in order to facilitate comparison of the resolutions.
- Stereonet projections were created of the average coarse, average fine, and the interpolated difference (fine - coarse) results of both phytoplankton groups.
- Total biomass (petagrams C) were compared across both resolutions by integrating the concentration of phytoplankton carbon over the Southern Ocean (south of 35°S) and to the bottom of the well-lit euphotic zone.
- In this integration, we assume that the phytoplankton concentration is constant through the euphotic zone, and that the depth of the euphotic zone is 100m every-where.
- Stereonet projections of averaged and interpolated ice cover, sea surface temperature, and dissolved inorganic iron were also created, as these are important factors that limit where phytoplankton occur.

Results: Resolution vs. Pg Carbon

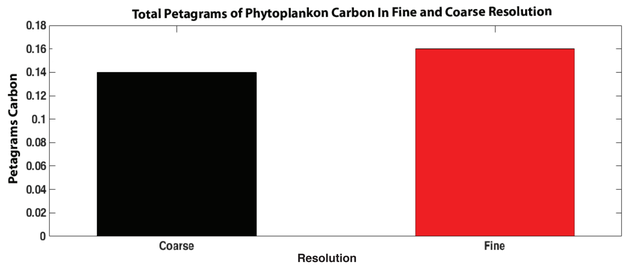


Figure 2: Bar graph of the total amount of carbon in the surface layer of the Southern Ocean for each model output. The sum for both diatom and small phytoplankton carbon for the coarse output was 0.14 Pg. The fine output produced 0.16 Pg of carbon. There is a 12.5% difference between the coarse and fine resolution phytoplankton carbon.

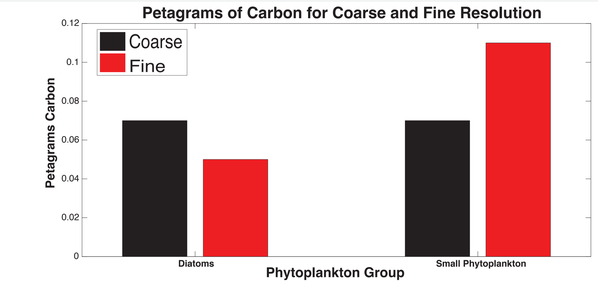


Figure 3: Bar graph of phytoplankton carbon separated for diatoms and small phytoplankton over both resolutions. The coarse resolution produced 0.07 Pg C for both diatoms and small phytoplankton. The fine resolution simulated 0.05 Pg of diatom carbon and 0.11 Pg of small phytoplankton carbon.

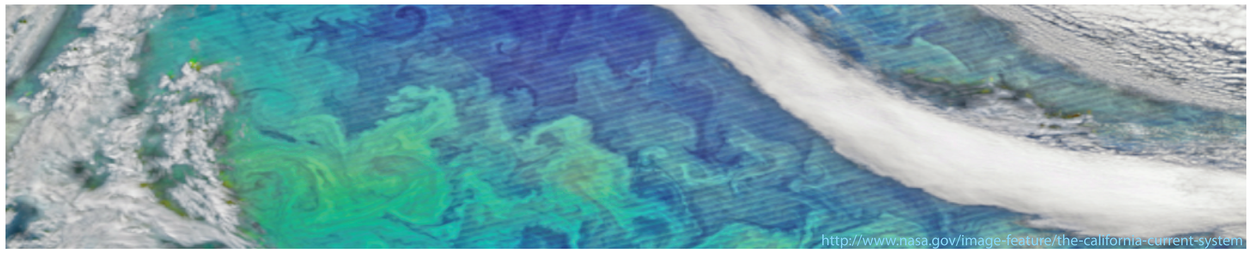
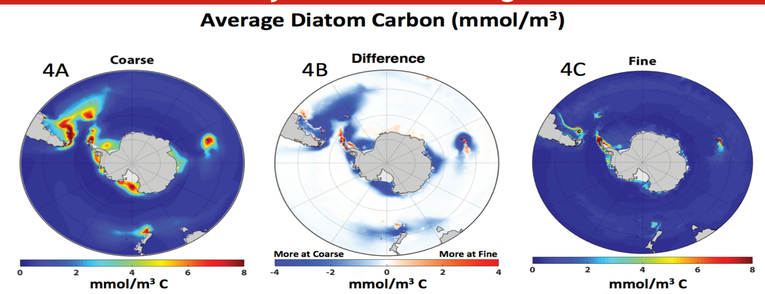
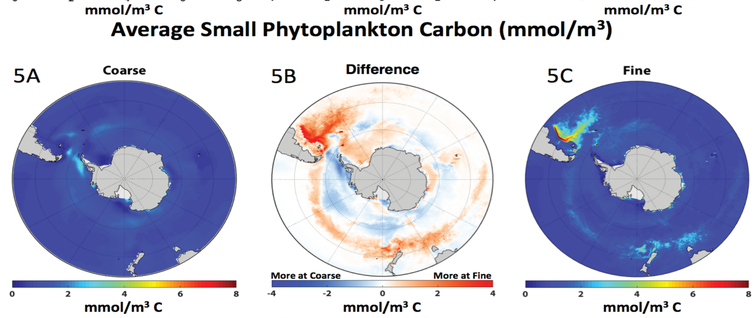


Figure 1: A phytoplankton bloom in the North Atlantic. Phytoplankton blooms occur at different times of the year and in different locations of the planet. When they bloom is dependent on limiting factors of light availability, sea surface temperature, and nutrient availability. Different groups of phytoplankton require varying amounts of each limiting factor with certain groups growing where others do not.

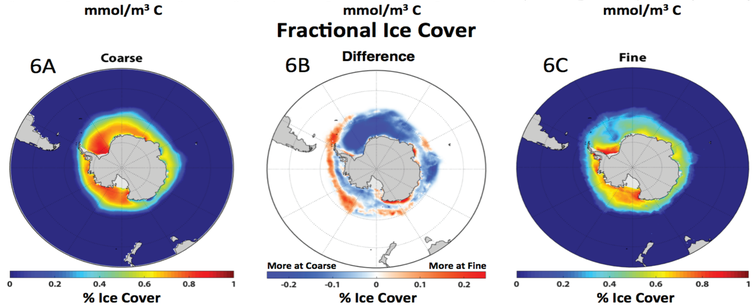
Results: Stereonet Projections of Averaged Factors



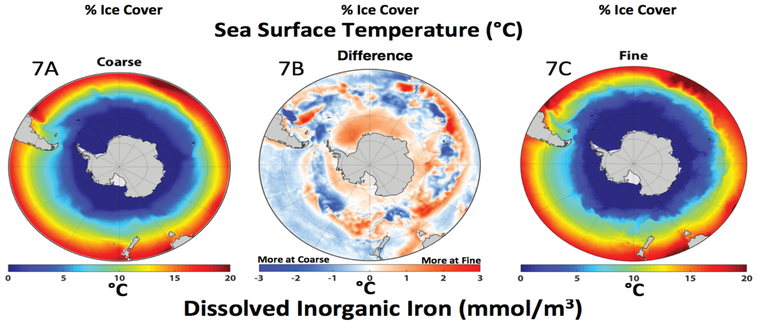
Figures 4A-4C: Stereonet projections of average diatom carbon over coarse (4A) and fine (4C) resolution. Figure 4B is a stereonet projection of the difference between coarse and fine model output diatom concentrations (shown as fine minus coarse).



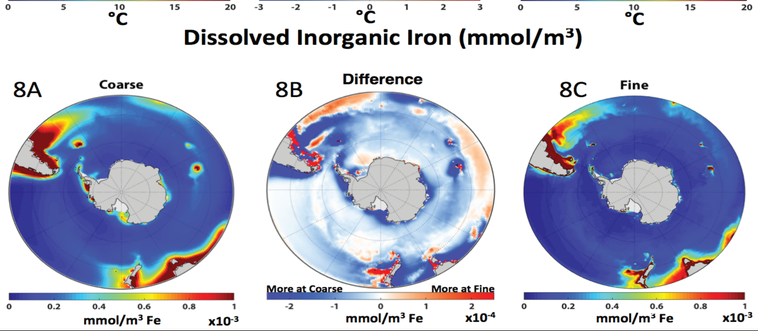
Figures 5A-5C: Stereonet projections of average small phytoplankton carbon over coarse (5A) and fine (5C) resolution. Figure 5B is a stereonet projection of the interpolated difference between coarse and fine small phytoplankton output. The fine output shows a very high concentration of average small phytoplankton over the Patagonian shelf and also below southern New Zealand. The only location where small phytoplankton truly appear in the coarse resolution are on the western side of the Antarctic peninsula.



Figures 6A-6C: Average Southern Ocean ice cover over coarse (6A) and fine (6C) resolution. Figure 6B is the difference between the coarse and interpolated fine fractional ice cover. The coarse output simulates a much higher fraction of ice in the Weddell and Ross seas while that ice coverage is lower at fine resolution, where we find a much lower fractional ice cover, on average. This discrepancy can be seen in figure 6B where the blue color (representing the coarse resolution's output) covers a dense swath of the Weddell sea.



Figures 7A-7C: Average Southern Ocean sea surface temperature over coarse (7A) and fine (7C) resolution. Figure 7B is the difference between the coarse and interpolated fine sea surface temperature. A filament of colder temperature along the Patagonian Shelf is more visible in the ne resolution than the coarse resolution.



Figures 8A-8C: Average Southern Ocean dissolved in-organic iron over coarse (8A) and fine (8C) resolution. Figure 8B is the difference between coarse and interpolated fine dissolved inorganic iron. A filament of low-iron water is visible in the fine resolution model along the Patagonian shelf, and may be responsible for the distinct biogeography of the two phytoplankton groups.

Discussion and Conclusions

- The integrated phytoplankton carbon content in the Southern Ocean is very similar across the two model resolutions.
- However, there is more diatom carbon at coarse resolution, and more small phytoplankton carbon at fine resolution.

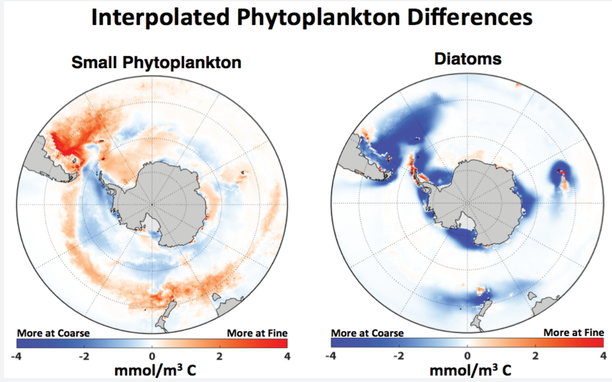


Figure 9: Interpolated differences between resolutions of diatoms and small phytoplankton. The small phytoplankton dominate the fine resolution model output while the diatoms dominate the coarse resolution model output.

- The Patagonian Shelf exhibited the largest difference in phytoplankton species abundance across the two resolutions.
- There is a 36% difference in small phytoplankton biomass across the fine and coarse resolution.
- Cooler SST and more ice cover in the coarse resolution account for the higher amount of diatoms, which prefer sub-polar conditions.
- We recommend the use of the fine resolution model when analyzing phytoplankton biogeography. The fine resolution captures a more detailed image of the phytoplankton community dynamics.
- Future work will include comparing model output to real world satellite estimates to evaluate the validity of both model resolutions.

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Acknowledgements

I would like to thank UNAVCO and the RESESS Internship for this research opportunity. Aisha Morris, Jacky Baughman, Peter Shellito, and Rolf Norgaard were invaluable resources over the coarse of this project. I would also like to thank INSTAAR's Nikki Lovenduski for her mentorship and her graduate students Kristen Krumhardt and Natalie Freeman for their MATLAB and writing assistance.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

This material is based upon work supported by the National Science Foundation Under Grant No. 1261833.

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