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Interactive comment on "Climate change impacts on net primary production (NPP) and export production (EP) regulated by increasing stratification and phytoplankton community structure in CMIP5 models" *by* W. Fu et al.

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1 Reply to Reviewers, BGD November 2015

We thank the reviewers for their comments and suggestions on this manuscript. We present some general comments first and then address specific comments below. We were unaware of the Cabre et al. (2015) paper at submission, but we will compare many aspects of our results with this work in a revised manuscript. Both Cabre et al.

(2015) and Bopp et al. (2013) examined the same group of CMIP 5 ocean biogeochemical models as this work. We feel this work strongly complements these two excellent papers. Bopp et al. (2013; and to some extent Cabre et al., 2015) focus more on model-mean responses, and model trends normalized to 1990s values, emphasizing similarities in the model responses to climate change. Cabre et al. (2015) also include detailed analysis of key ocean biomes and changes between the beginning and end of the century under RCP 8.5.

The emphasis in our work is partly on illustrating the wide spread across models for key biogeochemical and physical metrics from the current era, and understanding how that impacts the responses to climate change. Secondly, we wanted to identify, at the global scale, what drives the climate change responses in NPP and sinking export production. The CMIP5 ocean biogeochemical models are an increasingly important component of our climate projections (i.e. Randerson et al., 2015). Considering the vast resources committed (both human and computational), and the societal importance of predicting how the Earth system will respond to climate change, we agree with Reviewer #1 that there needs to be much more study of these models, from different perspectives. CMIP5 marks the first time ocean biogeochemistry has been included in most of these Earth System Models, and detailed documentation of model performance and results is necessary. Quantifying each model's performance relative to current-era observations, also allows for objective evaluation over time as to whether these models are improving. The target audience for this work includes the oceanographic and broader climate communities.

There are a number of new results and perspectives presented here, that are not found in previous works. Both reviewers note our novel finding that the models with the strongest positive biases in stratification for the 1990s, also show the strongest increases in stratification and the largest decreases in export production and NPP with climate change.

We present times series of the absolute values (not normalized to each model mean *for some period) key physical and biogeochemical variables, illustrating the wide inter-model spread (and comparison to observed values) in surface nutrient concentrations (Figure 5), productivity and export (Figure 8), and sea surface temperature, salinity, and surface stratification (Figure 1). We also show 2-D maps of surface nitrate for the 1990s from all the models compared with the World Ocean Atlas (Figure 7). These figures thus allow readers to examine each model's fidelity to observations for the current era, and illustrate the large spread across the models. No plots like these have appeared in prior works. Similarly, we show the 2-D spatial patterns for diatom contribution to NPP and the particle export ratio (Figures 11 and 13), and the 2d patterns of how these change with climate (Figures 12 and 14). This complements the biome by biome analysis of by Cabre et al. (2015), and illustrates the links between plankton community composition and export efficiency.*

We emphasize comparing the biogeochemical variables with stratification as a key driver, as this metric better captures high-latitude, salinity-driven climate impacts than SST alone. We also present 2D plots showing where warming and salinity changes dominate the stratification changes for each model (Figure 3), and show the spatial patterns of stratification change by the end of the century (Figure 4). Previous works have focused on the model-mean response, we highlight the similarities and the disagreements across the models in the spatial patterns of stratification change and in the dominant process driving stratification changes (temperature vs. salinity).

Our analysis of the impacts of changing stratification on biogeochemical variables utilizes the full time series from each model, rather than just comparing the beginning and end of the century. We examine how stratification impacts biogeochemistry, phytoplankton community structure, and export efficiency using 150 data points for each model (Figure 10). Rather than just one or two points per model, based on beginning and end of century, decadal time-scale means. Thus our regressions and illustrations of the similarities and differences across the models are more robust, and are more easily visualized in the plots for each model, than in previous analyses (Figure 10).

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Please note that we already published a paper comparing global response of phytoplankton and PP over the 21st century in the entire suite of CMIP5 models (http://link.springer.com/article/10.1007/s00382-014-2374-3). We discussed the primary production responses across models on a biome by biome basis and found many of the same patterns. It would be interesting to discuss how your new results fit our earlier findings.

As noted in the previous sections, we were not aware of this publication at the time of manuscript submission. We thank the author for pointing it out. We feel our revised manuscript will strongly complement this work and we will make detailed comparisons where appropriate in the revised manuscript.