Reply to Referee #2

Referee comment: Throughout the paper, please be careful with the usage of the word "data". Both model output and observations are data and sometimes it is rather confusing if "data" is used without further specification, particularly if the application of the word switches between modelled and observational data. I recommend for most cases to replace the word data with the word "observations" (where applicable) and use model data or model output at others.
Author's response: we see that this can be a problem.
Changes to the manuscript: We have checked the manuscript throughout and changed from 'data' to observations' or 'observational data' where we thought it may have been unclear if the data are from the model or the observations. Where observations are described as 'in-situ', 'observed' or 'satellite' we consider that it is clear that these are observational data and we have not changed these.

Referee comment: I would recommend using names for the model versions discussed rather than the use of: the current version, this version, the original version, the version from 1998 . . ..
Changes to the manuscript: We have followed the reviewer's suggestion where applicable and referred to the specific versions listed in Table 1.

Referee comment: Revise title to somehow include "Arctic" and "biogeochemical"
Author's response: Having a more specific title is a good suggestion, but the model covers more than just the Arctic, therefore we wanted to include North Atlantic as well.
Changes to the manuscript: We changed the title to: "Tuning and assessment of the HYCOM-NORWECOM V2.1 biogeochemical modeling system for the North Atlantic and Arctic"

Detailed comments:
Referee comment: p8400
(1) l 5 has -have
(2) l 7 The model revisions
(3) l 13/14 rm sentence "probably as a result...
Changes to the manuscript: We have changed (1) and (2), but for (3) we prefer to keep the sentence about improved circulation in the high-resolution models since we think this is an important point.

(4) l 24 BGC models are less accurate – what does that mean?
Author's response: What we mean by this is that while physical models are based on the well-established 'equations of motion' and the main challenges are in how these equations are represented numerically and how sub-grid processes and forcing are represented, the equations that are used to describe the system correctly are not known in biogeochemical models.
Changes to the manuscript: The new formulation is as follows "Not all biogeochemical processes in the ocean are well understood and therefore biogeochemical models are less accurate than circulation models both with respect to model formulations and parameterizations. Observational data for validation and model evaluation are more scarce than for circulation models."

Referee comment: p8401
 l 5/6 this sentence doesn't make sense
Changes to the manuscript: We added 'is': "…for estimating unknown parameters, the assimilation of ocean color data in operational models is underway."

Referee comment: p8402
*(1) l 8/9 suggest: ...for forecasting and regularly evaluated using
in sutu....and sea ice.*

(2) L 21 derived from GlobalNEWS model output
(3) L24 proved ???=> provided?
<u>Changes to the manuscript:</u> (1) This sentence was changes to "HYCOM is routinely used for forecasting and the predictions are regularly evaluated using in-situ and …". (2) and (3) was changed according to the reviewer's suggestion.

Referee comment: p8403
(1) L5 determine => determines
(2) L10 is – are
(3) L11 and silicate => and nitrate?
(4) L16/17 rephrase
(5) L23 the same as - derived from (or add "in")
<u>Changes to the manuscript:</u>
(1) and (3) has been corrected
(2) is kept as is, since it refers to 'the main distinction, which is singular.
(4) has been rephrased to "NORWECOM V2.0 was primarily applied to the North Sea, while HYCOM-NORWECOM, focused the open ocean regions of the North Atlantic, therefore the extinction coefficient due to water and non-chlorophyll substances was reduced from 0.07 to 0.04 (Hansen and Samuelsen, 2009)."
(5) we added 'in'

Referee comment: p8404
L20 runs, <u>to limit the </u>computational cots, as the 15km . . .
<u>Changes to the manuscript:</u> This was changed according to the reviewer's suggestion.

Referee comment: p8405
(1) suggest putting table 3 in an appendix
(2) L 5-7 confusing,
(3) rephrase L19 In the case that....=> In case of several . . .
(4) L20 Rm sentence One caveat...modelled chlorophyll superfluous
(5) 2.3 what data???
<u>Changes to the manuscript:</u>
(1) Table three has been moved an appendix
(2) The sentence has been changed to "In order to assess the effect of the revised parameter set on the 15-km model, two simulations were performed; one with the with the higher resolved grid (simulation names starting with TP); the original set of parameters (TP0) and one with revised set of parameters (TP1)."
(3) This was changed according to the reviewer's suggestion.
(4) This sentence was removed from that section, however we think this is an important piece of information, so we added the sentence "The model assumes constant N/Chl-ratio (11 g N/g Chl in the control run)." to the model description.
(5) New heading is "Description of observations"

Referee comment: p8406
*(1) L9 -11 shorten: A combination of metrics ** and ** was used.. ...are defined as:*
(2) Eq 6 what is n
(3) 2.5 put in appendix with table 3
<u>Changes to the manuscript:</u>
(1) The sentence now reads: "A combination of model efficiency (ME) and percentage model bias (Pbias) was used for the comparison between the model simulations and observations. These statistical quantities are defined as:"
(2)We have changed the sentence below eq 6 to "where D_n is observation from station n, M_n is the corresponding model estimate, $\bar{D}$ is the mean of the observations, and N is the total number of stations." Hopefully it is now clear what is the meaning of n and N.
(3) We would like to keep this in the main text, since this is a model description paper, we think this is essential information.

Referee comment: p8407
(1) L21 .. no skill => is this shown somewhere?
(2)L23 both runs????? there are 16 runs, do you mean both resolutions?
(3) L24 (Fig.5). - what about the few showing a positive bias?
Author's response:
(1) The sentence was meant to say 'lower skill', not 'no skill'
(3) In line 24 we are still talking about the runs with the original parameters, hopefully this is clear after the rephrasing of the sentence below.
Changes to the manuscript:
(1) The first paragraph in section 3.1 has ben rewritten for better clarity and the last sentence has been removed.
(2) and (3) The sentence has been changed to : "Hereby the runs with the original parameter set for both resolutions show no skill for the ME (figure 4) and large negative percentage biases (figure 5), meaning that the model consistently overestimates the chlorophyll."

Referee comment: p8408
(1) L1 ..is overestimated => Is this shown?
(2) L 2 We have also observed => found (keep the word observed for the observations)
(3) L3-5 In addition ... - this has already been stated (do not repeat)
(4) 3.2 Parameter alterations ???? better title?
(5) L 8 Many of the parameter ...
(6) L9 as seen in Figs 4 and 5 – Can't see the improvement in those figures, pls clarify
Author's response:
(1) This can be seen in the Taylor diagram (fig. 8 in the original paper) – we now refer to this figure and have renumbered it to figure 6.
(6) With the inclusion of numbers on figures 4 and 5 (as suggested by the first reviewer) it should be easier to see where there are improvements (or deterioration) now.
Changes to the manuscript:
(1) We have added a reference to figure 6 (former figure 8) in the sentence
(2) We now start the sentence with "Analysis have shown"
(3) We have removed this sentence
(4) We changed the title to "Parameter modifications"
(5) We added "the"
(6) The actual values are now added to figure 4 and 5.

Referee comment: p8410
(1) revised run – revised model/ or revised parameterisation
(2) L7 regions. In the Norwegian Sea observations are available throughout...
(3)L16 show – shows
(4) Watch the use of data, data, data....
(5) L25 has -have
Changes to the manuscript:
(1) 'revised run' has been changed to 'revised model run'
(2),(3) and (5) We followed the reviewers suggestion
(4) as said above, we have amended this.

Referee comment: p8411
(1) last paragraph of 3.3 What about the influence of ice algae? Make note
(2) Discussion: Try to minimize repetition, use concise sentences, please review for grammar
Author's response:
(1) We are not sure what the question is about the ice-algae, since we talk about a delay in the spring bloom in that paragraph; perhaps the question is if ice-algae can help influence the timing of the spring bloom. We are not sure if this is the case, but this would anyway only influence a very small part of the model domain and

not the large open ocean regions. We mention the lack of ice-algae in the model as a source of error in the discussion.

(2) We have carefully gone over the discussion section and checked for repetitions and to improve the language as was also asked for in the general comments to the paper.

Referee comment: p8412
(1) 8412 L 2 claims to the accuracy – what does that mean? ...accuracy can be relaxed ???
(2) L 7 research vessels paragraph on the quality of the observational data can be shortened
(3) L13 here the – here, are the outspell HPLC
(4) L 5 to 24 shorten, this has limited relevance to the paper
(5) L24-28 this is a known issue, does not need that much detail (does not more or less depend on the resolution, it does depend on the resolution)
Author's response:
(1) Note that we are talking about detecting changes, not detecting absolute values.
(2) We prefer to keep all of this information in the manuscript because we think it is important to have an understanding about the observations as well.
Changes to the manuscript:
(1) In order to clarify this, we rewrote the two sentences: "For example, for observing changes in the deep ocean, taking measurements one or a few times a year is enough, however changes in the deep ocean are so small that detecting changes require large accuracy. In comparison, the coastal areas and surface waters needs to be measured substantially more often in order to capture the variability, but since these waters have large variability the requirements to accuracy can often be relaxed."
(2) We deleted "to the spatial and temporal limitation of the observations" in the last sentence.
(3) We have written out HPLC: High-performance liquid chromatography and changed 'here the' to 'here, are the'
(4) For the same reason as the response to (2) we have kept the information, but rephrased the text.
(5) We removed " more or less"

Referee comment: 4.2 restructure and shorten: suggest: parameter changes with little impact are: with high impact … not analyzed ..
E.g. sentence
Changes in the zooplankton mortality also had little effect on the results, this is the closure term in the model and it is a bit surprising that this term only had a small effect on the model results.
Changes to the manuscript: The sentence was changed to "The zooplankton mortality is the closure term in the model, but contrary to other studies (e.g (Steele and Henderson, 1992) perturbations of this parameter had little effect on the results." As said before, we have carefully gone through all of the discussion section.

Referee comment: p8415
(1) L 7 Ice front => ice edge ?
(2) L 9 large error => error of what?
(3) L7-14 rephrase, shorten
(4) L 15 severe – clear
(5) L18 showed – shown
(6) L 20 The model is late ??? The spring bloom is simulated late
(7) L 23 What does phyto convection mean
Author's response:
(7) Phyto-convection is the early seeding of the spring bloom by phytoplankton that was mixed down during winter.
Changes to the manuscript:
(1), (4) and (5)Was changes as the reviewer suggested.

(2) added "errors in chlorophyll or nutrient"

(3) The paragraph has been rephrased, it may not be shorter, some unnecessary information has been omitted.

(6) We changed the sentence before to include the information about the late spring bloom and deleted the first part of that sentence, including the formulation in question.

(7) We chose to keep this as is as it is quite well known and interested readers can read the Backhouse paper, but we now write 'phyto-convection process'

Referee comment: p8416
(1) The meaning of the first paragraph is not clear, rephrase also rephrase
(2) L 9-11 Last sentence is unnecessary and can be removed.
(3) Table 2 This table is somewhat confusing Do the ratios need to be given in mg/mg and mmol/mmol ?? Maybe one conversion info as a table footnote is sufficient > For several runs two representations are given for pi21, should one be pi23?
(4) For N14 => diatomer – diatoms
(5) Fig 3 fall and autumn refer to the same season :-) I think the first should be spring and summer
(6)Fig 4 If not defined in caption refer to text: Model efficiency (ME, see text)
(7) Fig 3-7 dataset => observations Fig.8 what does "Data" mean ?
Changes to the manuscript:
(1) This paragraph has been rephrased.
(2) This part has been removed, but a shorter version of the same information is included in the first paragraph of what I now termed 'Conclusion'
(3) Yes, we agree it is unnecessary to give both units, we have chosen to keep the numbers in units of mg/mg since the model operates in units of mg.
(4), (5) and (6) This has been corrected according the reviewers suggestion
(7) We have gone through the manuscript and checked out uses of data, it has been changed in the figure labels as well.