Automated calibration of earth system model biogeochemistry

Ocean biogeochemical parameter optimisation in an offline earth system model

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In Short

- A suite of 4 calibrations are underway to ascertain the impact of uncertainties in the model physics on calibration.
- The resultant calibrated models will then be forced using an increasing atmospheric CO_2 concentration scenario to explore differences in model response to climate warming over a 100 year timescale.
- These simulations are designed to explore the uncertainty envelope of biogeochemical model response to climate warming, constrained by optimal parameter fit to nutrient and oxygen observations and observations of maximum meridional overturning.

Background

Equilibrated global ocean biogeochemical models produce different results when integrated with different biogeochemical parameters, e.g. [1–3]. The differences can be the same order of magnitude as those induced by physical differences [4] in the circulation. Few studies exist of how biogeochemical parameter differences affect transient projections of biogeochemistry (though [5] and [6] are two recent exceptions) because earth system and ocean models typically vary in both their biogeochemical and physical setup, e.g. [7,8], as well as in how they are spun up [9].

We are systematically exploring the uncertainty space of biogeochemical model sensitivity to physical parameterisation and biogeochemical parameter choice in an offline framework. This framework exploits the hundred-fold increase in computational efficiency provided by the Transport Matrix Method (TMM) [10,11] to calibrate biogeochemical parameters in an ocean model using a range of search algorithms and metrics [12,13] (this work falls within the scope of HLRN projects shk00025 and shk00033). The framework has been adapted to the University of Victoria Earth System Climate Model (UVic ESCM), where the stand-alone biogeochemistry is referred to as UVOK [14,15]. The advantage of working with the UVic ESCM is that results from offline simulations can be easily and quickly applied in fully-coupled earth system and transients simulations, to test for resulting systemic sensitivity on e.g., the carbon cycle.

Our initial proposal outlined a comparison of 5 identical biogeochemical parameter calibrations using 3 different vertical mixing schemes and a range of meridional overturning strengths to demonstrate the effect of physics on optimal parameter identification. Four calibrations were funded and are underway, following the methods of [12].

First Results

Our project has experienced delays detailed in our progress report. To date, one calibration is nearly complete and appears to have converged in less time than expected (Figure 1). The other three are about 30% complete and are converging more slowly. It is still too early to make a preliminary comparison between calibrations. However, the Bryan-Lewis vertical mixing calibration appears to be converging on a parameter set that shows some distinct differences to our hand-tuned model (compare thin black lines to the thick black lines in the figure). For example, the resulting light attenuation parameter is more than double the default model value. This should make an interesting transient climate forcing test, because the UVic ESCM response to climate warming has been shown to be very sensitive to this parameter [5].

Future Objectives and Methods

We would like to continue with our plan to define an uncertainty envelope of biogeochemical model response to climate warming, constrained by optimal parameter fit to nutrient and oxygen observations and observations of maximum meridional overturning. We still propose 3 identical biogeochemical calibrations of the model using 3 commonly used vertical mixing schemes (Bryan-Lewis [16], spatially constant vertical diffusivity, and a tidally-driven mixing scheme) tuned to an average global maximum meridional overturning strength of 17.5 Sverdrups, and one tidally-driven model tuned to 20 Sv [17]. Calibration methods will continue to follow those outlined in [12] and in HLRN project shk00025. The suite of calibrated models can then be forced with increasing atmospheric CO_2 concentrations to explore

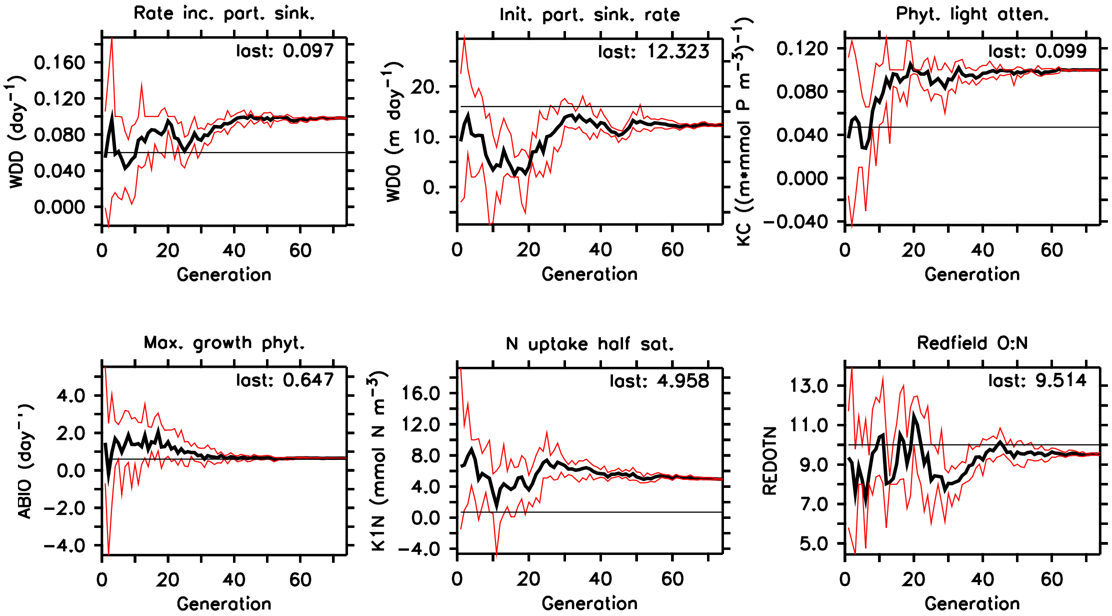

Figure 1: *Resulting parameter values of a UVOK calibration using the Bryan-Lewis vertical mixing scheme. Thin black lines denote default model parameter values. Thick black lines are the average parameter values for all 10 individuals of a generation. Red lines are the maxium and minimum parameter values for each generation. A full calibration should take 100-150 generations.*

differences in fully-coupled UVic ESCM response to climate warming.

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More Information

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