Master thesis at Climate and Environmental Physics

Is the ocean carbon sink predictable on interannual-to-decadal timescales? (60 ECTS)

The world ocean is a major sink for anthropogenic carbon absorbing about 30% of the CO_2 released each year by human-induced carbon emissions [*Le Quéré et al.*, 2016]. Recent research suggests that the ocean carbon sink is very variable on interannual-to-decadal timescales [*Landschützer et al.*, 2016; *McKinley et al.*, 2016]. For example, over the last two decades, the Southern Ocean has shown large fluctuations going from reduced uptake to reinvigorated uptake [*Landschützer et al.*, 2015]. It is currently unclear for how long the increased carbon uptake observed during the 2000s will persist in the coming years to decades. This is of significant concern, as countries need to know the compatible CO_2 emissions in advance in order to comply with the Paris agreement goal of keeping global warming well below 2°C above preindustrial. This can only be achieved if all sources and sinks of atmospheric CO_2 over the next years to decades are known. Current decadal prediction efforts have focused mainly on the predictability of the physical climate system, but our understanding of predictability of the ocean carbon sink is still in its infancy.

The student will assess and quantify the potential predictability of the ocean carbon fluxes, and will identify the underlying mechanisms in the coupled system that serve to prescribe the degree of predictability. To do this, the student will use model output from a suite of large ensemble forecasts from different initial condition states identified with a state-of-the-art global coupled Earth system model (GFDL ESM2M [Dunne et al., 2012, 2013]). The model has been re-forecasted for specific time intervals with large decadal changes in the ocean carbon sink from the control simulation using the same ("perfect") model. For each re-forecast, the model initial conditions are given infinitesimal perturbations for each of the 40 ensemble members. Predictability will be assessed by comparing the numerical forecasts with forecasts from simple statistical models, like climate or persistence forecast, or a forecast from a multi-variate regression model. These models will need to be trained within the spectrum of variance offered by the numerical model. Subsequently different verification measures will be invoked to assess the predictability of the ocean carbon sink. The basis for these measures is presented in Jolliffe and Stephenson (2011). With these analyses, the student will be able to not only estimate the upper limit of ocean carbon flux predictability, but also to develop mechanistic insights into the limits on predictability.

Project tasks and time frame

- Get familiar with the computer system, the ensemble simulations, and the current state of knowledge and theory on verification (months 1-3)
- Start with analysis of the model simulations and program simple statistical models for verification. Write the chapters on theory of predictability, methods and model and simulation description (months 4-6)
- Finalize the analysis and write results chapter. Start with the introduction (months 7-9)
- Finalize thesis: interpretation of the results, discussion and comparison with existing literature (months 10-12)

Further information:

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