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Why different gas flux velocity parameterizations result in so similar flux results in the North Atlantic?

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The North Atlantic is a crucial region for both ocean circulation and the carbon cycle. Most of ocean deep waters are produced in the basin making it a large CO_2 sink. The region, close to the major oceanographic centres has been well covered with cruises. This is why we have performed a study of net CO_2 flux dependence upon the choice of gas transfer velocity k parameterization for this very region: the North Atlantic including European Arctic Seas. The study has been a part of a ESA funded OceanFlux GHG Evolution project and, at the same time, a PhD thesis (of I.W) funded by Centre of Polar Studies “POLAR-KNOW” (a project of the Polish Ministry of Science). Early results have been presented last year at EGU 2015 as a PICO presentation EGU2015-11206-1.

We have used FluxEngine, a tool created within an earlier ESA funded project (OceanFlux Greenhouse Gases) to calculate the North Atlantic and global fluxes with different gas transfer velocity formulas. During the processing of the data, we have noticed that the North Atlantic results for different k formulas are more similar (in the sense of relative error) that global ones. This was true both for parameterizations using the same power of wind speed and when comparing wind squared and wind cubed parameterizations. This result was interesting because North Atlantic winds are stronger than the global average ones. Was the flux result similarity caused by the fact that the parameterizations were tuned to the North Atlantic area where many of the early cruises measuring CO_2 fugacities were performed?

A closer look at the parameterizations and their history showed that not all of them were based on North Atlantic data. Some of them were tuned to the South Ocean with even stronger winds while some were based on global budgets of 14C. However we have found two reasons, not reported before in the literature, for North Atlantic fluxes being more similar than global ones for different gas transfer velocity parametrizations.

The first one is the fact that most of the k functions intersect close to 9 m/s, the typical North Atlantic wind speeds. The squared and cubed function need to intersect in order to have similar global averages. This way the higher values of cubic functions for strong winds are offset by higher values of squared ones for weak ones. The wind speed of the intersection has to be higher than global wind speed average because discrepancies between different parameterizations increase with the wind speed. The North Atlantic region seem to have by chance just the right average wind speeds to make all the parameterizations resulting in similar annual fluxes.

However there is a second reason for smaller inter-parameterization discrepancies in the North Atlantic than many other ocean basins. The North Atlantic CO_2 fluxes are downward in every month. In many regions of the world, the direction of the flux changes between the winter and summer with wind speeds much stronger in the cold season. We show, using the actual formulas that in such a case the differences between the parameterizations partly cancel out which is not the case when the flux never changes its direction.

Both the mechanisms accidentally make the North Atlantic an area where the choice of k parameterizations causes very small flux uncertainty in annual fluxes. On the other hand, it makes the North Atlantic data not very useful for choosing the parameterizations most closely representing real fluxes.