A neural network-based estimate of the seasonal to inter-annual variability of the Atlantic Ocean carbon sink

The Atlantic Ocean is one of the most important sinks for atmospheric carbon dioxide (CO2), but this sink is known to vary substantially in time. Here we use surface ocean CO2 observations to estimate this sink and the temporal variability from 1998 to 2007 in the Atlantic Ocean. We benefit from (i) a continuous improvement of the observations, i.e., the Surface Ocean CO2 Atlas (SOCAT) v1.5 database and (ii) a newly developed technique to interpolate the observations in space and time. In particular, we use a 2 step neural network approach to reconstruct basin-wide monthly maps of the sea surface partial pressure of CO2 (pCO2) at a resolution of 1° × 1°. From those, we compute the air–sea CO2 flux maps using a standard gas exchange parameterization and high-resolution wind speeds. The neural networks fit the observed pCO2 data with a root mean square error (RMSE) of about 10 μatm and with almost no bias. A check against independent time series data reveals a larger RMSE of about 17 μatm. We estimate a decadal mean uptake flux of −0.45 ± 0.15 Pg C yr⁻¹ for the Atlantic between 44° S and 79° N, representing the sum of a strong uptake north of 18° N (−0.39 ± 0.10 Pg C yr⁻¹), outgassing in the tropics (18° S–18° N, 0.11 ± 0.07 Pg C yr⁻¹), and uptake in the subtropical/temperate South Atlantic south of 18° S (−0.16 ± 0.06 Pg C yr⁻¹), consistent with recent studies. We find the strongest seasonal variability of the CO2 flux in the temperature driven subtropical North Atlantic, with uptake in winter and outgassing in summer. The seasonal cycle is antiphased in the subpolar latitudes relative to the subtropics largely as a result of the biologically driven winter-to-summer drawdown of CO2. Over the analysis period (1998 to 2007) sea surface pCO2 increased faster than that of the atmosphere in large areas poleward of 40° N, but many other parts of the North Atlantic increased more slowly, resulting in a barely changing Atlantic carbon sink north of the equator (−0.007 Pg C yr⁻¹ decade⁻¹). Surface ocean pCO2 was also increasing less than that of the atmosphere over most of the Atlantic south of the equator, leading to a substantial trend toward a stronger CO2 sink for the entire South Atlantic (−0.14 Pg C yr⁻¹ decade⁻¹). The Atlantic carbon sink varies relatively little on inter-annual time-scales (±0.04 Pg C yr⁻¹; 1σ).

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