README file
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Decadal Trends in the Oceanic Storage of Anthropogenic Carbon from 1994 to 2014

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Abstract

This NCEI accession consists of the estimated decadal changes in the oceanic content of anthropogenic CO_2 (ΔCant) between 1994, 2004 and 2014 as described in detail in Müller et al. (2023, in press, AGU Advances). These estimates have been derived from the GLODAPv2.2021 product (Lauvset et al., 2021) using the eMLR(C*) method developed by Clement & Gruber (2018). The datasets contain in addition to the standard estimate also 10 sensitivity cases, which are intended to assess the robustness of the standard estimates to different changes in the estimation procedure. All estimates are provided on a horizontal grid with 1° x 1° resolution. Two primary files are provided: one containing the full three-dimensional distribution of ΔCant and one containing the vertically integrated values, i.e., the column inventories. These data provide strong constraints on the decadal variability of the oceanic sink for anthropogenic CO2, and given the global nature of our assessment also constraints on the global carbon budget. The estimates will prove also useful to assess ocean acidification and evaluate ocean models with regard to their carbon uptake and storage.

Method

The observation-based estimates of the change in anthropogenic CO2 content (ΔCant) in the ocean between 1994, 2004 and 2014 were generated using the eMLR(C*) method introduced and described in detail by Clement & Gruber (2018). Briefly, this method relies on dissolved inorganic carbon (DIC) observations from GLODAPv2.2021 (Lauvset et al., 2021), which are processed in three steps. In the first step, the semi-conservative tracer C* = DIC – 117×[PO43-] – 0.5×(TA + 16×[PO43-]) is computed from the measured DIC, alkalinity [TA] and phosphate ([PO43-]) content assuming constant stoichiometric C:P (117:1) and N:P (16:1) ratios during photosynthesis and respiration. In the second step, all data are allocated to either the first (1989–1999), second (2000–2009), or third (2010–2020) sampling period and then adjusted to the reference year of the respective period (1994, 2004 or 2014) based on a transient steady state assumption. In the third step, the data from each sampling period are fitted using multiple linear regression (MLR) models with a combination of up to seven predictor variables. For the MLR fitting, the data are vertically binned into ranges of neutral density, i.e., isoneutral slabs, and horizontally into ocean basins. The best fitting MLR models for each spatial bin and each pair of two sampling periods are selected and then used together with climatological distributions of the predictor variables to map out C* for each reference year to the global ocean. Finally, ΔCant is determined as the difference between two C* distribution fields. A suite of 10 sensitivity cases were run in order to explore the robustness of the estimated ΔCant to a range of subjective choices in the estimation procedure. These subjective choices can be categorised into two main groups, namely the basin mask definition used for the horizontal binning of the data and the exact configuration of the eMLR(C*) method.

Description of NetCDF files

File 1: dcant_emlr_cstar_mueller_94-04-14.nc

This file contains the full three-dimensional fields (lon x lat x depth) of the ΔCant estimates for the two periods 1994 - 2004 and 2004 - 2014. In total, 11 ΔCant estimates are provided that were obtained by using different basin mask definitions for the horizontal binning of the data (dimension name: MLR_basin_mask) and modifying the exact configuration of the eMLR(C*) method (dimension name: MLR_configuration). The standard case ΔCant estimates are those with the dimensions MLR_basin_mask = “3” and MLR_configuration = “Standard case”. In addition, 10 ΔCant sensitivity cases are provided, half of which were obtained by using a different basin mask definition and the other half by modifying the exact configuration of the eMLR(C*) method. All estimates are provided on a 1° x 1° horizontal grid and 33 uneven depth levels. The dcant variable contains the estimated ΔCant in units of µmol kg-1 decade-1.

File 2: inv_dcant_emlr_cstar_mueller_94-04-14.nc

This file contains two-dimensional fields (lon x lat) of the vertically integrated changes in Cant, i.e., the ∆Cant column inventories integrated over the top 3000m of the water column. Except for the absence of the depth dimension, all dimensions in this file are identical to those described above for the three-dimensional fields, including the identification of the standard and 10 sensitivity cases. The dcant_inv variable contains the ∆Cant column inventories in units of mol m-2 decade-1.

File 3: inv_dcant_emlr_cstar_mueller_94-04-14_uncertainty.nc

This file contains uncertainty estimates for the two-dimensional ∆Cant column inventories, derived from the offsets between the standard estimate and the 10 sensitivity cases. Except for the absence of the two dimensions that distinguish the 11 cases (MLR_basin_mask and MLR_configuration) and a reduction of the horizontal resolution to a 5° x 5° horizontal grid, all dimensions in this file are identical to those described above for the two-dimensional ∆Cant column inventories. The dcant_inv variable contains the ∆Cant column inventories at reduced horizontal resolution and the dcant_inv_uncertainty variable contains the corresponding uncertainty. Both variables are provided in units of mol m-2 decade-1.

File 4: surface_area_mask_emlr_cstar_mueller_94-04-14.nc

This file contains the surface areas associated with the 1° x 1° horizontal grid of the two- and three-dimensional fields provided in files 1 and 2. The surface_area variable is given in units of m2.

File 5: volume_mask_emlr_cstar_mueller_94-04-14.nc

This file contains the volumes associated with the three-dimensional fields (lon x lat x depth) of the estimates provided in file 1. The depth levels provided as a dimension in the file refer to the depth at which ∆Cant was estimated. The volume estimates represent the depth layers extending half way up- and downward between the depth layers. For example, the depth layer associated with the depth level of 3000m ranges from 2750m to 3250m, because the nearest depth layers are located at 2500m and 3500m. The volume estimates were obtained as the product of the thickness of the depth layers (500m in the example mentioned before) and the surface area estimates provided in file 4. The volume variable is given in units of m3.

File 6: basin_mask_emlr_cstar_mueller_94-04-14.nc

This file contains the 6 basin mask definitions that were used to bin data horizontally for the fitting of MLR models. The 6 basin masks are provided on a 1° x 1° horizontal grid and distinguished by the dimension MLR_basin_mask. The variable sub_basin_name is a counter variable to identify the individual regions of each basin mask definition.

Note for users

For most purposes, the standard case ∆Cant estimate (MLR_basin_mask = “3”; MLR_configuration = “Standard case”) is the best one to be used. The other sensitivity cases are primarily relevant for users who want to derive uncertainties for specific ∆Cant estimates obtained by integrating or averaging over the three-dimensional fields provided in file 1. For this purpose we recommend applying the same procedure as described in section S4 of the supplement to Müller et al. (2023).

When using the volume mask file for the vertical integration of ∆Cant estimates, please note that the volume estimates refer to the depth layers extending half way up- and downward between the depth layers given in the dimensions of the file. Thus, if users want to reproduce for example our column inventory estimates integrated over the top 3000m, the volume associated with the 3000m depth levels needs to be divided by 2, as the corresponding depth layer extends from 2750m to 3250m.

For the conversion of the ∆Cant content unit from kg-1 to m-3, a conversion factor of 1030 was used. For the unit conversion from mol to g of carbon, a molar mass of 12 g mol-1 was used. These conversions are required to obtain column or basin inventories from the three-dimensional ∆Cant estimates provided in file 1.

Inquiries

Inquiries should be sent to Jens Daniel Müller: jensdaniel.mueller@usys.ethz.ch

Code availability

The R-code underlying this data set is split up into different processing steps and available through Zenodo under following digital object identifiers.
Preprocessing of observational data: https://doi.org/10.5281/zenodo.7997243
Running eMLR analysis: https://doi.org/10.5281/zenodo.4630046
Analysing eMLR output: https://doi.org/10.5281/zenodo.7997221
Utility code: https://doi.org/10.5281/zenodo.7997233

References

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