



1 A synthesis of **SNAPO-CO2** ocean total alkalinity and total dissolved
2 inorganic carbon measurements from 1993 to 2022.

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4 Nicolas Metzl¹, Jonathan Fin^{1,2}, Claire Lo Monaco¹, Claude Mignon¹, Samir Alliouane³,
5 David Antoine^{3,4}, Guillaume Bourdin⁵, Jacqueline Boutin¹, Yann Bozec⁶, Pascal Conan^{7,8},
6 Laurent Coppola^{3,8}, Frédéric Diaz^{*}, Eric Douville⁹, Xavier Durrieu de Madron¹⁰, Jean-Pierre
7 Gattuso^{3,11}, Frédéric Gazeau³, Melek Golbol^{8,12}, Bruno Lansard⁹, Dominique Lefèvre¹³,
8 Nathalie Lefèvre¹, Fabien Lombard^{3,14}, Férial Louanchi¹⁵, Liliane Merlivat¹, Léa Olivier¹,
9 Anne Petrenko¹³, Sébastien Petton¹⁶, Mireille Pujo-Pay⁷, Christophe Rabouille⁹, Gilles
10 Reverdin¹, Céline Ridame¹, Aline Tribollet¹, Vincenzo Vellucci^{8,12}, Thibaut Wagener¹³, Cathy
11 Wimart-Rousseau^{13,17}

12

13 ¹ Laboratoire LOCEAN/IPSL, Sorbonne Université-CNRS-IRD-MNHN, Paris, 75005, France

14 ² OSU Ecce Terra, Sorbonne Université-CNRS, Paris, 75005, France

15 ³ Sorbonne Université, CNRS, Laboratoire d'Océanographie de Villefranche, LOV, F-06230 Villefranche-sur-
16 Mer, France

17 ⁴ Remote Sensing and Satellite Research Group, School of Earth and Planetary Sciences, Curtin University,
18 Perth WA 6845, Australia

19 ⁵ School of Marine Sciences, University of Maine, Orono, USA

20 ⁶ Station Biologique de Roscoff, UMR 7144 – EDYCO-CHIMAR, Roscoff, France

21 ⁷ Sorbonne Université, CNRS, Laboratoire d'Océanographie Microbienne, LOMIC, F-66650 Banyuls-sur-Mer,
22 France

23 ⁸ Sorbonne Université, CNRS, OSU Station Marines, STAMAR, Paris, F-75006, France

24 ⁹ Laboratoire des Sciences du Climat et de l'Environnement, LSCE/IPSL, UMR 8212 CEA- CNRS-UVSQ,
25 Université Paris-Saclay, 91191 Gif-sur-Yvette, France

26 ¹⁰ CEFREM, CNRS-Université de Perpignan Via Domitia, 52 Avenue Paul Alduy, 66860 Perpignan, France

27 ¹¹ Institute for Sustainable Development and International Relations, Sciences Po, 27 rue Saint Guillaume, F-
28 75007 Paris, France

29 ¹² Sorbonne Université, CNRS, Institut de la Mer de Villefranche, IMEV, Villefranche-sur-Mer, F-06230, France

30 ¹³ Aix Marseille Univ, Université de Toulon, CNRS, IRD, MIO, Marseille, France

31 ¹⁴ Research Federation for the study of Global Ocean Systems Ecology and Evolution, FR2022/Tara GOSEE,
32 75000, Paris, France.

33 ¹⁵ CVRM: Laboratoire de Conservation et de Valorisation des Ressources Marines, Ecole Nationale Supérieure
34 des Sciences de la Mer et de l'Aménagement du Littoral (ENSSMAL), Station de recherche de Sidi Fredj,
35 Algeria

36 ¹⁶ Ifremer, Univ Brest, CNRS, IRD, LEMAR, F-29840 Argenton, France

37 ¹⁷ Marine Biogeochemistry, GEOMAR Helmholtz Centre for Ocean Research Kiel, 24105 Kiel, Germany

38 ^{*} Passed away 14/3/2021

39 *Correspondence to:* Nicolas Metzl (nicolas.metzl@locean.ipsl.fr)

40 **Abstract.** Total alkalinity (A_T) and total dissolved inorganic carbon (C_T) in the oceans are important properties
41 to understand the ocean carbon cycle and its link **with climate change (ocean carbon sinks and sources) or global**
42 **change (ocean acidification)**. We present a data-base of more than 44 400 A_T and C_T **observations** in various
43 ocean regions obtained since 1993 mainly in the frame of French projects. This includes both surface and water
44 column **s** data acquired in open ocean **s**, coastal zones and in the Mediterranean Sea and either from time-series or
45 punctual cruises. Most A_T and C_T data in this synthesis were measured from discrete samples using the same
46 closed-cell potentiometric titration calibrated with Certified Reference Material, with an overall accuracy of ± 4
47 $\mu\text{mol kg}^{-1}$ for both A_T and C_T . **Given the lack of observations in the Indian and Southern Oceans**, we added sea



48 surface underway A_T and C_T data obtained in 1998-2018 in the frame of OISO cruises and in 2019 during the
49 CLIM-EPARSES cruise measured onboard using the same technique. **Separate datasets** for the global ocean, and
50 for the Mediterranean Sea are provided in a single format (<https://doi.org/10.17882/95414>, Metzl et al., 2023)
51 that offers a direct use for regional or global purposes, e.g. A_T /Salinity relationships, long-term C_T estimates,
52 constraint and validation of diagnostics C_T - A_T reconstructed fields or ocean carbon and coupled climate/carbon
53 models simulations, as well as data derived from **BG**-ARGO floats. When associated with other properties, these
54 data can also be used to calculate pH, fugacity of CO_2 ($f\text{CO}_2$) and other carbon systems properties to derive
55 ocean acidification rates or air-sea CO_2 fluxes.

56

57 **1 Introduction**

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59 Since 1750, humans activities have added 700 (± 75) PgC to the atmosphere by burning fossil fuels,
60 producing cement and changing land use (Friedlingstein et al., 2022) driving up the atmospheric carbon dioxide
61 (CO_2) concentration and leading to unequivocal global **warming**. The ocean plays a major role in reducing the
62 impact of climate change by absorbing more than 90% of the excess heat in the climate system (Cheng et al.,
63 2020; von Schuckmann et al., 2020, 2023; IPCC, 2022) and about 25% of human released CO_2 (Friedlingstein et
64 al., 2022). However, the oceanic CO_2 uptake changes the chemistry of seawater reducing its buffering capacity
65 (Revelle and Suess, 1957) and leading to a process known as ocean acidification with potential impacts on
66 marine organisms (Fabry et al., 2008; Doney et al., 2009, 2020; Gattuso et al., 2015). With atmospheric CO_2
67 concentrations, surface ocean temperature and ocean heat content, sea-level, sea-ice and glaciers, the ocean
68 acidification (decrease of pH) is now recognized as one of the 7 key properties for global climate **indicators**
69 (WMO, 2018). In the frame of the 2030 Agenda, the United Nations established a set of Sustainable
70 Development Goals (SDG; United Nations, 2020), including a goal dedicated to the ocean (SDG 14, "Life below
71 water") which calls to "conserve and sustainably use the oceans, seas and marine resources for sustainable
72 development". Ocean acidification is specifically referred in the SDG indicator 14.3.1 coordinated at the
73 Intergovernmental Oceanographic Commission (IOC) of UNESCO. Observing the carbonate system in the
74 oceans and marginal seas and understanding how this system changes over time is thus highly relevant not only
75 to quantify the global ocean carbon budget, the anthropogenic CO_2 inventories or ocean acidification rates, but
76 also to understand and simulate the processes that govern the complex CO_2 cycle in the ocean and to better
77 predict **future climate and global changes** (Eyring et al., 2016; Kwiatkowski et al., 2020; Jiang et al., 2023a).

78 The number and quality of ocean $f\text{CO}_2$, A_T , C_T and pH measurements has increased substantially over
79 the past few decades. Quality-controlled observations are now regularly assembled in global data syntheses such
80 as SOCAT (Surface Ocean CO_2 Atlas, Pfeil et al., 2013; Bakker et al., 2014, 2016) and GLODAP (Global Ocean
81 Data Analysis Project, Key et al., 2004; Olsen et al., 2016, 2019, 2020; Lauvset et al., **2021**). These datasets
82 allow evaluation of properties trends in the global ocean, including the change of the ocean CO_2 sink (e.g.
83 Wanninkhof et al., 2013; Friedlingstein et al., 2022; Watson et al., 2020), anthropogenic CO_2 inventories (e.g.
84 Sabine et al., 2004; Khatiwala et al., 2013; Gruber et al., 2019) and ocean acidification (Lauvset et al., 2015,
85 2020; Jiang et al., 2019). Thanks **to the GLODAP data-base**, new methods were recently developed (Sauzède et
86 al., 2017; Bittig et al., 2018) to reproduce A_T and C_T distributions from other properties like temperature, salinity
87 and oxygen more often observed in the water column especially from autonomous floats (Claustre et al., 2020;
88 Mignot et al., 2023). These methods (named CANYON-B and CONTENT, Bittig et al., 2018) are now also used
89 to help decisions on GLODAP data quality control or to fill in observational gaps (Olsen et al., 2019, 2020;



90 Tanhua et al., 2019, 2021). The GLODAP data-products were also successfully used to construct new global
91 ocean A_T and C_T climatological monthly fields in surface and water column using neural network method (e.g.
92 Broullón et al., 2019, 2020).

93 Following pioneer works that produced various global-ocean climatologies of the sea-surface carbonate
94 system (Millero et al., 1998; Lee et al., 2000, 2006; Takahashi et al., 2002, 2009, 2014; Sasse et al., 2013; Jiang
95 et al., 2019), the coupling of fCO_2 data (from SOCAT) and A_T data (from GLODAP) now enables reconstruction
96 of the full carbonate system in the surface ocean at monthly scale to investigate temporal trends at decadal scale
97 (e.g. Gregor and Gruber, 2021; Keppler et al., 2023).

98 International projects such as SOCAT and GLODAP offer important way to synthesize ocean carbon
99 data. In these projects, each observation is quality controlled offering to users high quality observations for
100 regional or global analysis, either for processes analysis or to constraint or validate of ocean and coupled
101 climate/carbon models (CMIP6, e.g. Lerner et al., 2021). SOCAT is a publicly available synthesis product
102 initiated in 2007 (Metzl et al., 2007) for quality-controlled, surface ocean fCO_2 (fugacity of carbon dioxide)
103 observations made by the international marine carbon research community (Bakker et al., 2016). The first
104 SOCAT version was released in 2011 (Pfeil et al., 2013; Sabine et al., 2013), followed by 6 SOCAT versions
105 (Bakker et al., 2014, 2016). The last version in 2023 includes more than 40 million fCO_2 data with accuracy
106 better than $5 \mu atm$ (Bakker et al., 2023). One important product from SOCAT is the use of data to estimate
107 global air-sea CO_2 fluxes based on reconstructed pCO_2 fields (e.g. SOCOM project, Surface Ocean pCO_2
108 Mapping Intercomparison, Rödenbeck et al., 2015). Since 2015, these results are included each year for the
109 global carbon budget (Le Quere et al., 2015; Friedlingstein et al., 2022).

110 On the other hand, following WOCE/JGOFS era in the 90s when almost all observations were started to
111 be synthesized in a specific recommended format (Joyce and Corry, 1994), GLODAP focusses on water-column
112 carbon observations (and other properties). Following the original GLODAP data-product (Key et al., 2004), the
113 project accumulated many new quality controlled observations. One important achievement from GLODAP is
114 the use of data to estimate the anthropogenic CO_2 inventory or its change over decades (Sabine et al., 2004;
115 Gruber et al., 2019). Both products, SOCAT and GLODAP, are relevant tools to detect oceanic acidification
116 rates (Lauvset et al., 2015; Jiang et al., 2019).

117 Although these projects include many international ocean observations there are ocean CO_2 related
118 observations all around the world (published or not published), such as total alkalinity and dissolved inorganic
119 carbon, not included in SOCAT or GLODAP. This is because SOCAT accepts and controls only fCO_2 data,
120 whereas GLODAP includes and controls water-columns data mainly from WOCE/GO-SHIP/CLIVAR cruises. It
121 should be noticed that many ocean carbon observations in various formats can be also found in dedicated data-
122 base such as NCEI/OCADS (former CDIAO-Ocean, Jiang et al., 2013b,
123 <https://www.ncei.noaa.gov/products/ocean-carbon-acidification-data-system>), PANGAEA
124 (<https://www.pangaea.de/>) or SeaNoe (<https://www.seanoe.org/>). In this context it is recommended to progress in
125 data synthesis of the ocean carbon observations that would offer new high quality products for the community
126 (e.g. for GOA-ON, www.goa-on.org, IOC/SDG 14.1.3, <https://oa.iode.org/>, Tilbrook et al., 2019).

127 In this work, we present a synthesis of more than 44 400 A_T and C_T observations obtained over the
128 1993-2022 period during various cruises or at time-series stations mainly supported by French projects. This
129 dataset merges observations measured with the same instruments thus being analytically coherent. Most of the
130 data have accuracy better than $\pm 4 \mu mol kg^{-1}$, i.e. between the climate ($\pm 2 \mu mol kg^{-1}$) and weather ($\pm 10 \mu mol kg^{-1}$)



131 ¹⁾ goals (Bockmon and Dickson, 2015). Hereafter this dataset will be cited as SNAPO-CO₂. We describe the
132 data assemblage and associated quality control and discuss some potential uses of this dataset.

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134 **2 Data collections**

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136 The time series projects and research cruises from which data were collated are listed in Table 1 with
137 references in the Supplementary file (SNAPO-CO₂-cruises) and the sampling locations displayed in Figure 1.
138 Sampling was performed either from CTD-Rosette casts (Niskin bottles) or from the ship's seawater supply
139 (intake at about 5m depth depending the ship and swell). Samples collected in 500 mL borosilicate glass bottles
140 were poisoned with 100 to 300 µL of HgCl₂ depending on the cruises, closed with greased stoppers (Apiezon®)
141 and held tight using elastic band following the SOP protocol (Dickson et al., 2007). Some samples were also
142 collected in 500 mL bottles closed with screw caps. After completion of each cruise, discrete samples were
143 returned back to the LOCEAN laboratory (Paris, France) and stored in a dark room at 4 °C before analysis
144 generally within 2-3 months after sampling (sometimes within a week). Some samples were also measured for
145 specific processes studies on benthic corals (e.g. Maier et al., 2012; McCulloch et al., 2012) or for mesocosm
146 and culture experiments but the data are not included in this synthesis as they do not represent natural ocean state
147 (e.g. addition of Sahara dust during the DUNE project, Ridame et al., 2014).

148 As opposed to pCO₂, surface A_T or C_T observations are generally obtained from discrete sampling
149 (measured onboard or onshore). Few cruises offer sea-surface semi-continuous A_T or C_T observations (e.g. Metzl
150 et al., 2006) but new instrumental developments now enable A_T measurements on SOOP lines, Ship of
151 Opportunity Program (Seelmann et al., 2020). In addition to discrete samples analyzed for various projects
152 conducted mainly in the North Atlantic, Tropical Atlantic, Tropical Pacific, Mediterranean sea and coastal
153 regions (Table 1), we complemented this synthesis with A_T and C_T surface observations obtained in the Indian
154 and Southern oceans during the OISO cruises in 1998-2018 (Metzl et al., 2006; Leseurre et al., 2022; data also
155 available at NCEI/OCADS: www.nodc.noaa.gov/ocads/oceans/VOS_Program/OISO.html) and the recent CLIM-
156 EPARSEES cruise conducted in the Mozambique Channel in April 2019 (Lo Monaco et al., 2020, 2021). For
157 OISO cruises the water-column observations are part of the CARINA (CARbon IN the Atlantic) and GLODAP
158 synthesis products (Lo Monaco et al., 2010; Olsen et al., 2016, 2019, 2020) and not included here. Excepted
159 when specified, all data in this synthesis were obtained using the same technique used either in laboratory or at
160 sea (for OISO 1998-2018 and CLIM-EPARSEES 2019 cruises).

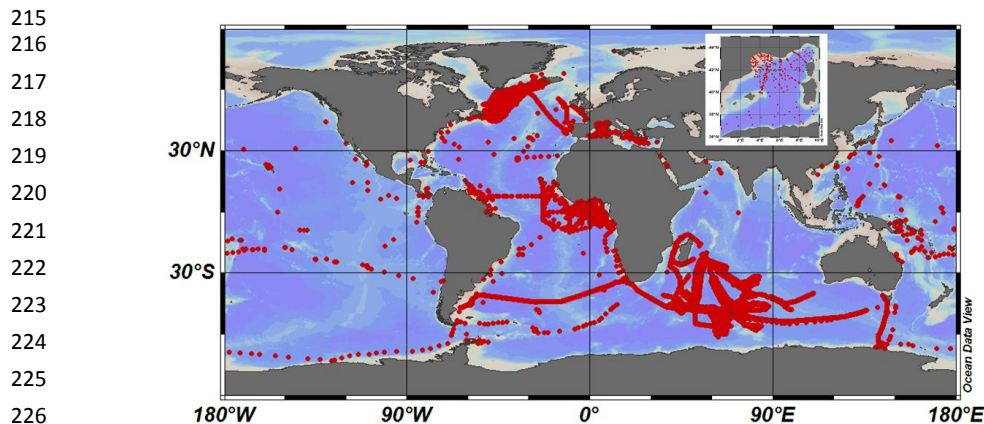
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162 **Table 1:** List of cruises in the SNAPO-CO2 dataset. This is organized by region: Global Ocean and coastal
 163 zones, and Mediterranean Sea (MedSea). See Tables S1, S2, S3 and S4 in the Supplementary Material for a list
 164 of laboratories, of CRMs used, for references and for DOI of cruises. Nb = the number of data for each cruise or
 165 time-series.

166	Cruise/Project	Start	End	Region	Sampling	Nb
167						
168						
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171	AWIPEV	2015	2021	Arctic	Surface and sub-surface	195
172	SURATLANT+RREX	1993	2017	North Atlantic	Surface	2832
173	OVIDE	2006	2018	North Atlantic	Surface, Water Column	397
174	STRASSE	2012		North Atlantic	Water Column	205
175	EUREC4A-OA	2020		North Atlantic	Surface, Water Column	135
176	PROTEUS	2010		North Atlantic	Water Column	27
177	CHANNEL	2012	2015	English Channel	Surface	696
178	SOMLIT-Brest	2008	2019	Coastal North Atl	Surface	1174
179	SOMLIT-Roscoff	2009	2019	Coastal North Atl	Surface and 60m	801
180	ECOSCOPIA	2017	2019	Coastal North Atl	Surface	67
181	PENZE	2011	2020	River Brittany	Surface and sub-surface	148
182	AULNE	2009	2010	River Brittany	Surface	27
183	ELORN	2009	2009	River Brittany	Surface	28
184	BIOZAIRE	2003	2004	Trop Atlantic	Water Column	87
185	EGEE	2005	2007	Trop Atlantic	Surface	199
186	PIRATA-FR	2009	2017	Trop Atlantic	Surface, Water Column	513
187	PLUMAND	2007		Trop Atlantic	Surface	38
188	OUTPACE	2015		Trop Pacific	Water Column	240
189	PANDORA	2012		Solomon Sea	Water Column	178
190	TARA-Pacific	2016	2018	Trop Pac, NATL	Surface and sub-surface	325
191	TARA-Ocean	2009	2012	Global Ocean	Surface + 400m	123
192	TARA-Microbiome	2021	2022	Atlantic	Surface, Water Column	216
193	ACE	2016	2017	Southern Ocean	Surface, Water Column	135
194	MOBYDICK	2019		Southern Ocean	Water Column	64
195	CLIM-EPARSES	2019		Indian	Surface	790
196	OISO	1998	2018	South Indian	Surface	24950
197						
198	DYFAMED	1998	2017	MedSea	Water Column	2118
199	BOUSSOLE	2014	2019	MedSea	Surface + 10m	172
200	SOMLIT-PointB	2007	2015	MedSea Coastal	Surface + 50m	2397
201	ANTARES	2010	2016	MedSea	Water Column	502
202	MOLA	2010	2013	MedSea Coastal	Water Column	66
203	SOLEMIO	2016	2018	MedSea Coastal	Water Column	212
204	MOOSE-GE	2010	2019	MedSea	Water Column	1847
205	LATEX	2010		MedSea	Water Column	51
206	CARBORHONE	2011	2012	MedSea	Water Column	706
207	CASCADE	2011		MedSea	Water Column	218
208	DEWEX	2013		MedSea	Water Column	367
209	SOMBA	2014	2014	MedSea	Water Column	203
210	AMOR-BFLUX	2015		MedSea Coastal	Water Column	6
211	PEACETIME	2017	2017	MedSea	Water Column	233
212	PERLE	2018	2021	MedSea	Water Column	805

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228 **Figure 1:** Locations of A_T - C_T data (1993-2022) in the Global Ocean and the Western Mediterranean Sea (insert).
229 Figure produced with ODV (Schlitzer, 2018).

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231 3 Method, accuracy, reproducibility, intercomparison and quality control

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233 3.1 Method and accuracy

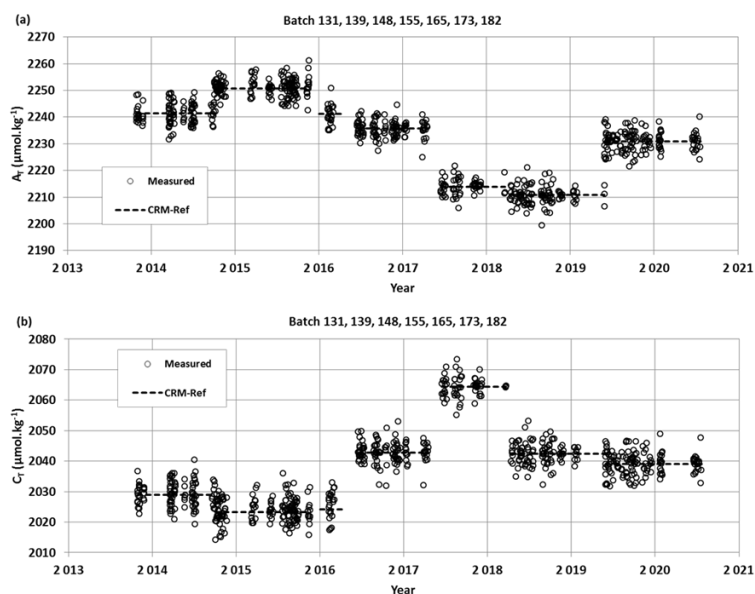
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235 Except for the DYFAMED time-series observations measured between in 1998 and 2000 in the
236 Mediterranean Sea (Copin-Montégut and Bégovic, 2002; Coppola et al., 2020; Lange et al., 2023), the
237 SURATLANT time-series values acquired from 1993 to 1997 in the North Atlantic subpolar gyre (Reverdin et
238 al., 2018) and samples measured in the river Penzé (Brittany) in 2019-2020 (Yann Bozec, SBR/Roscoff, pers.
239 comm.), all discrete samples were measured at LOCEAN laboratory in Paris (SNAPO-CO₂ Service facilities)
240 using the same technique. A_T and C_T were analyzed simultaneously by potentiometric titration using a closed cell
241 (Edmond, 1970; Goyet et al., 1991). In the late 1980s the so-called “JGOFS-IOC Advisory Panel on Ocean
242 CO₂” recommended the need for standard analysis protocols and for developing Certified Reference Materials
243 (CRMs) for inorganic carbon measurements (Poisson et al., 1990; UNESCO, 1990, 1991). The CRMs were
244 provided to international laboratories by Pr. A. Dickson (Scripps Institution of Oceanography, San Diego, USA),
245 starting in 1990 for C_T and 1996 for A_T , respectively. These CRMs were thus always available to us and used to
246 calibrate the measurements (CRM Batch numbers used for each cruise are listed in Supplementary file (Table
247 S2).

248 Results of analyses performed on 724 CRM bottles (different Batches) in 2013-2020 are presented in
249 Figure 2. The standard deviations of the differences of measurements were on average around $\pm 3.5 \mu\text{mol kg}^{-1}$ for
250 both A_T and C_T . For unknown reasons, the differences were occasionally up to $10\text{-}15 \mu\text{mol kg}^{-1}$ (0.8% of the
251 data, Figure S2). These few CRM measurements were discarded for the data processing. On average, and
252 excluding some outliers, standard-deviations of the differences for 985 CRM analyses were $\pm 2.95 \mu\text{mol kg}^{-1}$ for
253 A_T and $\pm 3.30 \mu\text{mol kg}^{-1}$ for C_T , respectively. We did not detect any specific signal for these CRM analyses (e.g.,
254 larger uncertainty depending on the Batch number or temporal drifts during analyses, Figure 2) but for some
255 cruises and specific series of samples analyzed over 2 to 7 consecutive days, the accuracy based on CRMs could



256 be slightly better than $3 \mu\text{mol kg}^{-1}$ ($\pm 2.5 \mu\text{mol kg}^{-1}$) for both A_T and C_T , e.g. Marrec et al., 2014; Touratier et al.,
257 2016; Ganachaud et al., 2017; Wimart-Rousseau et al., 2020a).



278 **Figure 2:** A_T (a) and C_T (b) analyses for different CRM Batches measured in 2013-2020. For these 724 analyses
279 the mean and standard-deviations of the differences with the CRM reference were $-0.08 (\pm 3.35) \mu\text{mol.kg}^{-1}$ for A_T ,
280 and $0.15 (\pm 3.61) \mu\text{mol.kg}^{-1}$ for C_T .

281 282 3.2 Reproducibility and repeatability

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284 For some projects, duplicates have been regularly sampled (SOMLIT-Point-B, SOMLIT-BREST,
285 BOUSSOLE/DYFAMED) or replicate bottles sampled at selected depths at fixed stations during the cruises (e.g.
286 OUTPACE-2015, Wagener et al., 2018; SOMBA-2014, Keraghel et al., 2020). Results of A_T and C_T
287 reproducibility or repeatability are synthesized in Table 2. Figure 3 shows example of regular duplicates from the
288 times-series SOMLIT-Point-B in the coastal Mediterranean Sea (Kapsenberg et al., 2017), SOMLIT-Brest in the
289 Bay of Brest, coastal Iroise Sea (Salt et al., 2016) and BOUSSOLE/DYFAMED in the Ligurian Sea (Merlivat et
290 al., 2018; Golbol et al., 2000, 2020). For the 26 OISO cruises conducted between 1998 and 2018 and the CLIM-
291 EPARSES cruise in April 2019 (Lo Monaco et al., 2020, 2021), the repeatability was evaluated from duplicate
292 analyses (within 20 minutes time) of continuous sea surface underway sampling at the same location (when the
293 ship was stopped). Similarly to what was found for the CRM measurements (Figure S2), differences in
294 duplicates are occasionally higher than $10\text{-}15 \mu\text{mol kg}^{-1}$ (Figure 3) but most of the duplicates for all projects are
295 within 0 to $3 \mu\text{mol kg}^{-1}$. Based on the CRM analyses and replicates for different projects, different regions and
296 different periods, we estimated the accuracy for both A_T and C_T of $\pm 4 \mu\text{mol kg}^{-1}$.

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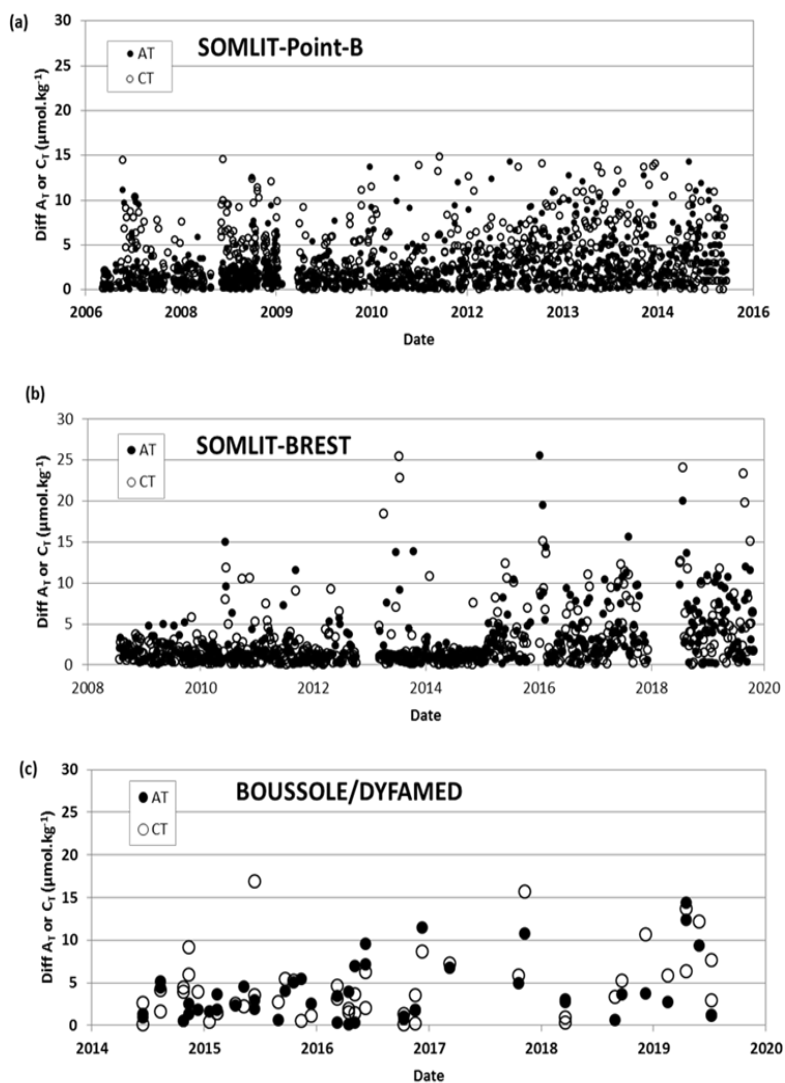


Figure 3: Results of duplicate A_T and C_T analyses from the time-series (a) SOMLIT-Point-B in the coastal Mediterranean Sea (Kapsenberg et al., 2017), (b) SOMLIT-BREST in the Bay of Brest, coastal Iroise Sea (Salt et al., 2016 and unpublished) and (c) BOUSSOLE/DYFAMED in the Ligurian Sea (Merlivat et al., 2018; Golbol et al., 2020). The plots show differences in duplicates for both A_T (filled circles) and C_T (open circles). Standard-deviations of these duplicates are listed in Table 2.



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344 **Table 2:** Reproducibility of A_T and C_T analyses for cruises with duplicate analysis. The results are expressed as
345 the standard-deviations (Std) of the analysis of replicated samples. Nb = the number of replicates for each Time-
346 series or Cruise. See Figure 4 for the results of regular duplicates for 3 Time-series (SOMLIT-Point-B,
347 SOMLIT-BREST, and BOUSSOLE). For OISO and CLIM-EPARSE cruises the results correspond to repeated
348 measurements from continuous sea surface underway sampling at the same location (i.e. within 20 minutes time
349 and when the ship was stopped). For the 26 OISO cruises (1998-2018) and for simplicity we list the mean
350 repeatability obtained for all cruises. Detail for each OISO cruise could be consulted in the associated metadata
351 online at NCEI/OCADS, www.nodc.noaa.gov/ocads/oceans/VOS_Program/OISO.html

Project-Cruise	Nb	Std A_T $\mu\text{mol kg}^{-1}$	Std C_T $\mu\text{mol kg}^{-1}$	Reference
OUTPACE	12	3.64	3.68	Wagener et al. (2018)
SOMBA	13	2.00	3.30	Keraghel et al. (2020)
SOMLIT-Point-B	786	2.63	3.10	Kapsenberg et al. (2017)
SOMLIT-Brest	446	3.34	3.67	Salt et al. (2016) + unpub
BOUSSOLE	48	3.47	4.02	Merlivat et al. (2018); Golbol et al. (2020)
CLIM-EPARSE	122	2.20	2.30	Lo Monaco et al. (2020, 2021)
OISO 1998-2018	1162	2.06	2.28	Metzl et al. (2006) and (*)

367 (*) Data available at www.nodc.noaa.gov/ocads/oceans/VOS_Program/OISO.html

3.3 Inter-comparisons

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371 Inter-comparisons of measurements performed with different techniques help to evaluate the quality of the
372 data and detect potential shifts (if any) when merging the data in the same region obtained by different
373 laboratories at different periods. This is especially important to interpret long-term trends of A_T and C_T as well as
374 for pCO_2 and pH calculated with A_T/C_T pairs. For ocean acidification studies, this also refers to the “climate
375 goal” for which an accuracy for A_T and C_T better than $\pm 2 \mu\text{mol kg}^{-1}$ is needed (Newton et al., 2015; Tilbrook et
376 al., 2019). Such inter-comparison thus helps to reflect the quality of the data to achieve either the so-called
377 “weather goal” (for A_T and C_T , $\pm 10 \mu\text{mol kg}^{-1}$) or the “climate goal” ($\pm 2 \mu\text{mol kg}^{-1}$) (Bockmon and Dickson,
378 2015). For the projects in this data synthesis, inter-laboratory comparisons were performed occasionally and
379 summarized below.

380 As part of the time-series CHANNEL (2012-2015) in the Western English Channel, Marrec et al.
381 (2014) analyzed surface samples collected bi-monthly in 2011-2013. A_T analyses were performed with a TA-
382 ALK-2 system (Appolo SciTech.) while C_T measurements were acquired with an AIRICA system (Marianda
383 Inc.) Based on CRM analyses (Batch #92) the accuracy was estimated $\pm 3 \mu\text{mol kg}^{-1}$ for A_T and $\pm 1.5 \mu\text{mol kg}^{-1}$
384 for C_T (Marrec et al., 2014). When comparing with the samples measured at LOCEAN/Paris for the year 2012,
385 Marrec et al. (2014) concluded that between the two methods the concentrations were within $\pm 2 \mu\text{mol kg}^{-1}$ and
386 $\pm 3 \mu\text{mol kg}^{-1}$ for A_T and C_T respectively. This is close to the “climate goal” offering confident results for long-
387 term trend analysis of the carbonate system in this region.

388 In the frame of the SURATLANT project in the Sub-Polar North Atlantic gyre, some samples collected
389 at the same time (in 2005, 2006, 2010, 2015, and 2016) were also analyzed onshore for A_T and/or C_T by other
390 laboratories using different techniques (e.g. coulometric method) and the results summarized by Reverdin et al.
391 (2018). For C_T , the mean differences between LOCEAN values and from 4 other laboratories range between -0.7
392 (± 4.6) and -6.5 (± 3.4) $\mu\text{mol kg}^{-1}$ depending on the cruise. For A_T the mean differences with 2 other laboratories



393 range from $-0.6 (\pm 4.1) \mu\text{mol kg}^{-1}$ to $+2.3 (\pm 4.8) \mu\text{mol kg}^{-1}$. These results range between the “climate goal” and
394 the “weather goal”. See Reverdin et al. (2018) for details on these inter-comparisons.

395 During OVIDE cruises conducted since 2002 in the North Atlantic along a section from Greenland to
396 Portugal (Lherminier et al., 2007; Mercier et al., 2015) samples have been taken (since 2006) to complement, for
397 summer, the SURATLANT time-series in the North Atlantic Sub-Polar gyre (NASPG). The OVIDE samples at
398 the surface and along the water-column at a few stations were measured back at LOCEAN for A_T and C_T (Metzl
399 et al., 2018). This enables us to compare our data with the measurements performed on-board by the IIM group
400 in Vigo/Spain (e.g. Pérez et al., 2010, 2013, 2018; Vazquez-Rodriguez et al., 2012). The OVIDE data have been
401 regularly quality controlled in CARINA and GLODAP data products (Velo et al., 2009; Key et al., 2010; Olsen
402 et al., 2016, 2019, 2020). The results of inter-comparisons are gathered in Table 3. For OVIDE in 2006 we
403 identified (for unknown reason) a large difference between our original A_T values compared to the A_T data
404 qualified in GLODAP and we thus corrected our A_T data by $+7.2 \mu\text{mol kg}^{-1}$. However, no correction was applied
405 for C_T . For other OVIDE cruises, differences for A_T range between $-4.5 (\pm 4.11) \mu\text{mol kg}^{-1}$ and $-0.05 (\pm 3.43)$
406 $\mu\text{mol kg}^{-1}$ depending on the cruise (i.e. A_T measured at LOCEAN was always slightly lower than onboard
407 measurements). For C_T , we compared our measurements onshore with C_T values calculated with A_T and pH
408 measured onboard. Most of the mean C_T differences are slightly positive (i.e. C_T measured at LOCEAN was
409 always higher, except for 2010). Taking into account all errors associated with the sampling, the transport of
410 samples, the instrumentations, the data processing, or the calculations for C_T , the comparisons between
411 LOCEAN and IIM data for OVIDE cruises are deemed acceptable and large differences for both A_T and C_T (> 4
412 $\mu\text{mol kg}^{-1}$) are far from being systematic (Table 3). The data from SURATLANT and OVIDE can then be
413 merged to complete the time-series in the NASPG in summer and to better describe the seasonality of the
414 oceanic carbonate system. For example, in 2010, when the North Atlantic Oscillation (NAO) was strongly
415 negative, the SURATLANT data showed a rapid decrease of C_T concentrations in the NASPG between early
416 June and August (Figure 4), with C_T concentrations in August much lower than other years (Racapé et al., 2014).
417 This leads to a rapid drop in $f\text{CO}_2$ in 2009-2010, such that the NASPG was a strong CO_2 sink (Leseurre et al.,
418 2020). The winter-to-summer seasonal decrease of C_T in 2010 in the north NASPG was on average $-77 \mu\text{mol}$
419 kg^{-1} (Figure 4) much larger than in the climatology (range -50 to $-55 \mu\text{mol kg}^{-1}$, Takahashi et al., 2014; Reverdin
420 et al., 2018). The OVIDE data in late June 2010 and SURATLANT in August 2010 confirmed this signal that
421 was linked to a pronounced primary productivity in that period (Figure 4, Henson et al., 2013; Racapé et al.,
422 2014; Mc Kinley et al., 2018). Notice that for this period no $p\text{CO}_2$ observations were available in July-September
423 2010 in SOCAT data-product and the A_T - C_T data presented here could be used to calculate $p\text{CO}_2$ to complement
424 the $p\text{CO}_2$ dataset in this region like was done for other periods (Mc Kinley et al., 2011).
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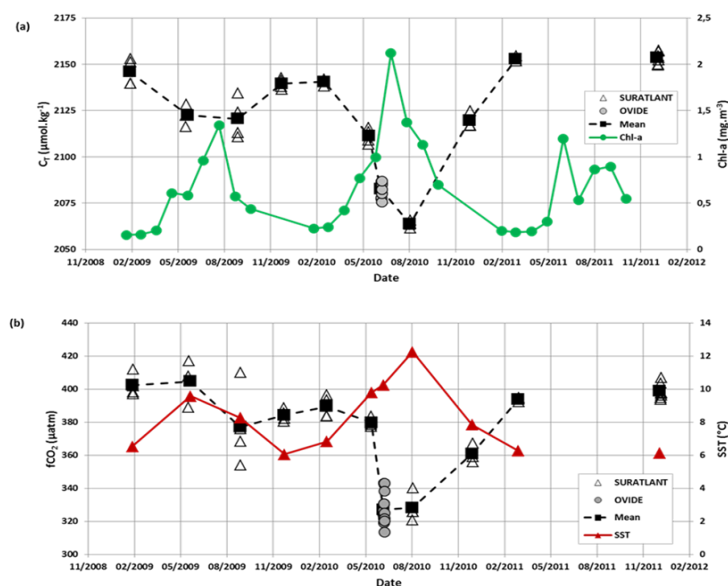


Figure 4: (a) Time-series of C_T concentrations ($\mu\text{mol.kg}^{-1}$) for 2009-2011 in surface waters in the North Atlantic Sub-Polar gyre (zone 59°N - 33°W) based on SURATLANT (open triangles) and OVIDE-2010 (grey circles) data. In 2009, SURATLANT data were available in February, June, September and December, while in 2010 data available in March, June, August and December and in 2011 data only available for March and December. The OVIDE data in late June 2010 completed the temporal cycle and confirmed the strong seasonal signal and low C_T concentrations in summer 2010 not seen in 2009 (or in 2011 as there is no data in summer). The mean observations for each period describe the C_T seasonal cycles in 2009 and 2010 (Black squares, dashed line). The monthly surface chlorophyll-a concentrations (Chl-a, mg.m^{-3}) averaged in the same region based on MODIS are also shown (Green dots and line) highlighting the high productivity during the summer 2010. Chl-a monthly data extracted from MODIS (Giovanni/NASA, last access 3/5/19). (b): Time-series of $f\text{CO}_2$ (μatm) for the same cruises (same symbols) calculated with A_T - C_T . Mean SST ($^\circ\text{C}$) indicated (red triangles). In June 2010 oceanic $f\text{CO}_2$ decreased by $53 \mu\text{atm}$ in 2 weeks.

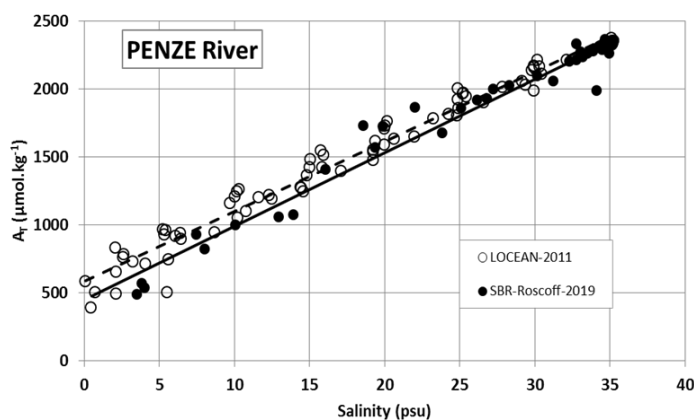
Table 3: Comparisons of A_T and C_T samples measured back at LOCEAN with measurements onboard by IIM Laboratory (F. Pérez, Vigo, Spain) for OVIDE cruises in the North Atlantic. Nb= Number of samples. ND= No Data. The results listed indicate the mean and standard deviations of the differences (LOCEAN-IIM). For A_T , IIM values were measured on-board. For C_T , IIM values were calculated from A_T and pH both measured onboard. The IIM data were quality controlled and here taken from the GLODAP data-products (Olsen et al, 2016, 2019).

Cruise Year	Nb A_T	A_T (LOCEAN) - A_T (IIM) $\mu\text{mol.kg}^{-1}$	Nb C_T	C_T (LOCEAN) - C_T (IIM) $\mu\text{mol.kg}^{-1}$
OVIDE-2006	14	-2.04 (\pm 5.84) (*)	14	1.12 (\pm 2.49)
OVIDE-2008	29	-4.53 (\pm 4.11)	29	3.76 (\pm 3.11)
OVIDE-2010	41	-1.96 (\pm 2.26)	41	-2.42 (\pm 3.35)
OVIDE-2012	37	-0.12 (\pm 8.85)	ND	ND
GEOVIDE-2014	57	-0.05 (\pm 3.43)	54	2.36 (\pm 7.89)

(*) for the OVIDE 2006 cruise original difference for A_T was $-9.0 (\pm 5.8) \mu\text{mol.kg}^{-1}$ and LOCEAN A_T data were corrected by $+7.2 \mu\text{mol.kg}^{-1}$ based on the mean concentrations in deep layers. No corrections were applied for A_T and C_T for other cruises.



482 The comparisons described above concern the open ocean region with A_T and C_T concentrations in a
483 range of concentrations close to the CRM references (used by the different laboratories). Another example of
484 comparison is presented here for samples obtained along a river and thus for waters with low salinity and A_T
485 concentrations (river Penzé in North Brittany). In 2019, A_T was measured at SBR laboratory (Station Biologique
486 de Roscoff) by a potentiometric method (using a Titrino-847 plus Metrohm) calibrated with CRM (Batch #131)
487 for a final accuracy of $\pm 2.1 \mu\text{mol kg}^{-1}$ (Gac et al., 2020). **Although the samples were measured with different**
488 **technics the A_T /Salinity relationships are very coherent for both datasets (Figure 5).** Therefore we added the A_T
489 data measured in 2019-2020 to complete the synthesis for this location (river Penzé).



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505 **Figure 5:** Total alkalinity (A_T) versus salinity for samples measured in 2011 and 2019 in the river Penzé, North
506 Brittany (Gac et al., 2020). A_T samples were measured at LOCEAN in 2011 (open circles, dashed-line) and at
507 SBR laboratory (Roscoff) in 2019 (filled circles, black line).

508 509 **3.4 Quality control and flags**

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511 Identifying each data with an appropriate flag is very convenient for selecting the data (good,
512 questionable or bad). Here we used 4 Flags for each property (Flags 2, 3, 4, and 9) following the WOCE
513 program and used in other data products such as SOCAT (Bakker et al., 2016) or GLODAP (Olsen et al., 2016,
514 2019, 2020; Lauvset et al., 2021). During the data-processing, we first assigned a flag for each A_T and C_T data
515 based on the standard error in the calculation of A_T and C_T concentrations (non-linear regression, Dickson et al.
516 2007). By default, if the standard-deviation on the regression is $> 1 \mu\text{mol kg}^{-1}$, we assigned a flag 3
517 (questionable) although the data could be acceptable and then used for interpretations. Flag 3 was also assigned
518 when salinity was doubtful or when differences of duplicates were large (e.g. $\pm 20 \mu\text{mol kg}^{-1}$). Flags 4 (bad or
519 certainly bad) were assigned when clear anomalies were detected for unknown reason (e.g. a sample probably
520 not fixed with HgCl_2). A secondary quality control was performed by the PIs of each project based on data
521 inspection, duplicates, A_T /Salinity relationship, or the mean observations in deep layers where large variability in
522 A_T and C_T is unlikely to occur from year to year. An example presents all data from the MOOSE-GE cruises
523 conducted in 2010-2019 in the Mediterranean Sea (Coppola et al., 2020; Testor et al., 2010) where clear outliers
524 have been identified (Figure S3). For the 10 MOOSE-GE cruises and a total of 1847 A_T and C_T analyses, 26 were
525 identified flagged as bad (flag 4), 139 for A_T and 141 for C_T listed as questionable (flag 3) and 1682 for A_T and



526 1680 for C_T considered as good data (flag 2, i.e. more than 90%). Similar control was performed for each
 527 project.

528 The synthesis of various cruises in the same region and period also offers verification and secondary
 529 control of the data. For example, several cruises were conducted in the Mediterranean Sea in 2014 (MOOSE-GE,
 530 SOMBA, ANTARES and DYFAMED). The mean values of C_T and A_T in the deep layers (> 1800m) for each
 531 cruise confirmed the coherence of the data (Table 4). This enabled to merge the different datasets for
 532 interpretations of the temporal trends and processes driving the CO_2 cycle (Coppola et al., 2019, 2020; Ulses et
 533 al., 2022) or to train and validate a regional neural network to reconstruct the carbonate system (e.g. CANYON-
 534 MED, Fourier et al., 2020, 2022).

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Table 4: Mean observations in the deep layers (> 1800m) of the western Mediterranean Sea for different cruises
 conducted in 2014. Results in deep layers (> 1800m) for the DEWEX cruise in 2013 and the PEACETIME
 cruise in 2017 in the same region are also listed. $N-A_T$ and $N-C_T$ are A_T and C_T normalized at Salinity = 38. Nb =
 number of data (with flag 2). Standard-deviations are in brackets. References for these cruises are listed in
 Supplementary Material.

Cruise	Period	Nb	Pot. Temp C	Salinity PSU	$N-A_T$ $\mu\text{mol kg}^{-1}$	$N-C_T$ $\mu\text{mol kg}^{-1}$
All cruises	Feb/Dec-2014	76	12.905 (0.007)	38.486 (0.005)	2562.9 (5.3)	2303.7 (4.7)
ANTARES	Feb/Nov-2014	14	12.913 (0.004)	38.488 (0.006)	2564.0 (3.8)	2301.9 (3.5)
DYFAMED	Mar/Dec-2014	9	12.905 (0.0016)	38.487 (0.004)	2560.1 (5.0)	2304.3 (6.8)
MOOSE-GE	Jul-2014	21	12.909 (0.004)	38.487 (0.005)	2565.6 (4.6)	2303.5 (4.1)
SOMBA	Aug/Sep-2014	32	12.899 (0.005)	38.483 (0.005)	2561.5 (5.6)	2304.6 (4.8)
DEWEX	Feb/Apr-2013	44	12.903 (0.010)	38.588 (0.006)	2556.0 (4.3)	2294.0 (5.7)
PEACETIME	May/Jun-2017	7	12.904 (0.002)	38.486 (0.003)	2567.2 (10.6)	2308.1 (8.9)

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571 The total number of data for the Global Ocean and the Mediterranean Sea are gathered in Table 5 with
 572 corresponding flags for each property. Overall, the synthesis includes more than 94% of good data for both A_T
 573 and C_T . About 5% are questionable and 2% are likely bad. Overall, we believe that all data (with Flag 2) in this
 574 synthesis have an accuracy better than $4 \mu\text{mol kg}^{-1}$ for both A_T and C_T , the same as for quality-controlled data in
 575 GLODAP (Olsen et al., 2020; Lauvset et al., 2021). The uncertainty ranges between the “Climate goal” ($2 \mu\text{mol}$
 576 kg^{-1}) and the “Weather Goal” ($10 \mu\text{mol kg}^{-1}$) for ocean acidification studies (Newton et al., 2015; Tilbrook et al.,
 577 2019). This accuracy is also relevant to validate or constraint data-based methods that reconstruct A_T and C_T



578 fields with an error of around 10-15 $\mu\text{mol kg}^{-1}$ for both properties (Bittig et al., 2018; Broullón et al., 2019, 2020;
579 Fourier et al., 2020; Chau et al., 2023).

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581 **Table 5:** Number of Temperature, Salinity, A_T and C_T data in the synthesis identified for Flags 2, 3, 4, 9. The
582 data are given for the full data-set Global Ocean and for the Mediterranean Sea. Last column is the percentage of
583 Flag 2 (Good).

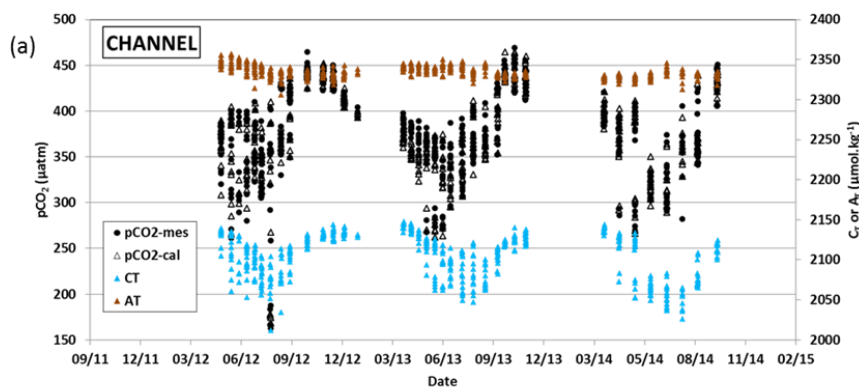
	Flag 2	Flag 3	Flag 4	Flag 9	% Flag 2
Global Ocean					
Temperature	43538	410	0	478	0.9907
Salinity	44033	319	2	71	0.9928
A_T	39331	2144	1165	1787	0.9224
C_T	39921	2091	1148	1279	0.9250
Mediterranean Sea					
Temperature	9843	1	0	65	0.9999
Salinity	9879	8	2	20	0.9999
A_T	8853	425	411	220	0.9137
C_T	8854	451	389	211	0.9133

3.5 Using A_T - C_T to calculate pCO_2 and pH and compare with pCO_2 and pH measurements

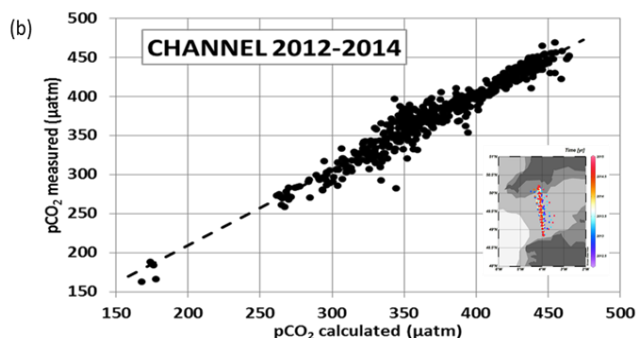
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608 For some projects, the A_T - C_T data presented in this synthesis were used to calibrate or validate in situ
609 pCO_2 sensors (Bozec et al., 2011; Marrec et al., 2014; Merlivat et al., 2018). The A_T - C_T data were also used to
610 calculate pCO_2 and to derive associated air-sea CO_2 fluxes, especially during periods when no direct pCO_2
611 measurements were available (e.g. in the North Atlantic, Figure 4, Watson et al., 2009; Mc Kinley et al., 2011).
612 For example, Marrec et al. (2014) successfully used the calculated pCO_2 (with A_T - C_T pairs) to adjust the drift of
613 the pCO_2 data recorded with a Contros-HydroC/ CO_2 FT sensor mounted on a FerryBox for regularly sampling
614 the Western English Channel. Here we show the results for the period 2012-2014 (Figure 6). In this region the
615 alkalinity is relatively constant over time; the average of A_T for 528 samples at different seasons and years is
616 2334.4 (± 7.2) $\mu\text{mol kg}^{-1}$. On the opposite, the C_T concentrations show distinctive seasonality, with higher
617 concentrations in winter and lower in summer when biological activity is pronounced (Marrec et al., 2013, 2014;
618 Kitidis et al., 2019). This controls the seasonal pCO_2 distribution revealed each year in both measured and
619 calculated pCO_2 (Figure 6). For 528 co-located samples the mean difference between calculated and measured
620 pCO_2 is -1.9 (± 11.9) μatm with no distinct differences depending on the season and year.
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648 **Figure 6:** (a): Time-series of A_T (brown triangles, right Y-axis), C_T (blue triangles, right Y-axis), pCO_2
649 calculated (open triangles, left Y-axis) and pCO_2 measured (filled circles) in the Western English Channel in
650 2012-2014 (Marrec et al., 2014). (b): Measured pCO_2 versus calculated pCO_2 for the same samples. The mean
651 difference ($pCO_{2cal} - pCO_{2mes}$) for 528 samples is $-1.9 \mu atm (\pm 11.9) \mu atm$. Data from Marrec and Bozec (2016
652 a,b; 2017). Localization of the samples is shown in the inserted map.
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654 In the Ligurian Sea, following the first high frequency in situ fCO_2 measurements in 1995-1997 at the
655 DYFAMED time-series station (Hood and Merlivat, 2001), a new CARIOCA fCO_2 sensor was deployed at that
656 location in 2013 (BOUSSOLE project, Merlivat et al., 2018). The CARIOCA sensor was calibrated with regular
657 A_T - C_T analyses performed at LOCEAN. **Based on these data, the mean difference between CARIOCA- fCO_2**
658 **measurements and calculated- fCO_2 data was estimated to be around $\pm 4.4 \mu atm$ for 2013-2015, i.e. the same**
659 **order than the precision of the CARIOCA sensor ($\pm 5 \mu atm$, Merlivat et al., 2018).** Here we extend the results for
660 the period 2013-2018 (Golbol et al., 2020; data also in SOCAT version v2021, Bakker et al., 2016) and
661 compared the CARIOCA fCO_2 time-series with A_T and C_T data from different cruises (BOUSSOLE,
662 DYFAMED and MOOSE-GE) selected in the layer 0-20m at that location (Figure S4). For 67 co-located
663 samples at different seasons and years, the mean difference between calculated and measured fCO_2 (fCO_{2cal} -
664 fCO_{2mes}) was $-3.7 \mu atm (\pm 10.8) \mu atm$. At that location, the alkalinity is relatively constant over 2013-2018 with
665 an average concentration of $2569.8 (\pm 13.2) \mu mol kg^{-1}$. C_T concentrations show a clear seasonality, decreasing by
666 around $50 \mu mol kg^{-1}$ from winter to late summer driving the large seasonal cycle of fCO_2 (range $80 \mu atm$)
667 revealed in both measured and calculated values (here fCO_2 is normalized at $13^\circ C$, Figure S4). In addition to
668 calibration purposes, a regional A_T /Salinity relationship was derived from the A_T data measured at that location
669 and successfully used to construct time-series of C_T and pH calculated from the high-frequency CARIOCA fCO_2



670 data to investigate and interpret the long-term change of $f\text{CO}_2$ and acidification in the Ligurian Sea (Merlivat et
671 al., 2018; Coppola et al., 2020).

672 A CARIOCA sensor was also deployed in 2003 near the SOMLIT-Brest time-series site in the Bay of
673 Brest (Bozec et al., 2011; Salt et al., 2016). As for BOUSSOLE in the Ligurian Sea, samples collected for A_T - C_T
674 were used for validation of the $p\text{CO}_2$ recorded by the CARIOCA sensor and the comparison with calculated
675 $p\text{CO}_2$ showed a good agreement, i.e. $p\text{CO}_{2\text{cal}} = 0.98 * p\text{CO}_{2\text{mes}} + 7 \mu\text{atm}$ (Bozec et al., 2011). CARIOCA
676 sensors were also deployed on moorings in the Tropical Atlantic (PIRATA project, e.g. Lefèvre et al., 2008,
677 2016; Parard et al., 2010). With the discrete A_T and C_T data included in this synthesis (EGEE and PIRATA-FR
678 cruises), the $f\text{CO}_2$ data from CARIOCA sensor associated with an adapted A_T /Salinity relationship were used to
679 derive pH (Lefèvre et al., 2016) or C_T time-series to evaluate net community production in the eastern tropical
680 Atlantic (Parard et al., 2010; Lefèvre and Merlivat 2012).

681 Although this is not a direct instrumental inter-comparison, differences between $p\text{CO}_2$ (or $f\text{CO}_2$)
682 calculated using A_T - C_T pairs with direct $p\text{CO}_2$ measurements give a glimpse of the quality of A_T and C_T data in
683 this synthesis given the uncertainty attached to the $p\text{CO}_2$ or pH calculations (Orr et al., 2015). For example, in
684 the frame of the SURATLANT project in the North Atlantic, calculated $f\text{CO}_2$ data were compared with co-
685 located $f\text{CO}_2$ measurements for different seasons and years (Figure S5). The mean differences ($f\text{CO}_{2\text{cal}} - f\text{CO}_{2\text{mes}}$)
686 ranged between $-4.3 \mu\text{atm}$ (± 12.9) μatm (2004-2007, 74 co-located samples) and -3.0 (± 12.1) μatm (2014-2015,
687 98 co-located samples). The differences are almost the same for different years (and seasons) and are thus
688 attributed to method uncertainties (including sampling time, measurement errors, and data processing). Based on
689 these comparisons and the consistency between data we are confident that the A_T - C_T data presented in this
690 synthesis could be used to calculate $f\text{CO}_2$ (and pH) and interpret temporal changes and drivers of these
691 parameters as well as to estimate air-sea CO_2 fluxes in the North Atlantic (e.g. Corbière et al., 2007; Schuster et
692 al., 2009, 2013; Watson et al., 2009; Metzl et al., 2010; Mc Kinley et al., 2011; Reverdin et al., 2018, Kitidis et
693 al., 2019; Leseurre et al., 2020).

694 The A_T - C_T data in this synthesis have been also successfully used for $f\text{CO}_2$ and air-sea CO_2 fluxes
695 calculations in other regions: the tropical Atlantic (Koffi et al., 2010), the tropical Pacific (Moutin et al., 2018;
696 Wagener et al., 2018), the Solomon sea (Ganachaud et al., 2017) or the Mediterranean sea and coastal zones (De
697 Carlo et al., 2013; Marrec et al., 2015; Kapsenberg et al., 2017; Coppola et al., 2020; Keraghel et al., 2020;
698 Wimart-Rousseau et al., 2020a; Gattuso et al., 2023).

699 In addition, A_T - C_T data in the surface and the water-column are also relevant to calculate pH and
700 evaluate its rate of change for addressing ocean acidification topic in different regions (Kapsenberg et al., 2017;
701 Ganachaud et al., 2017; Wagener et al., 2018; Coppola et al., 2020; Leseurre et al., 2020; Lo Monaco et al.,
702 2021). At the time-series station ECOSCOPA in the Bay of Brest (Fleury et al., 2023; Petton et al., 2023), pH
703 calculated with A_T - C_T data were compared with direct pH measurements (Figure S6). In 2017-2019, pH (at
704 standard temperature 25°C , pH-25C) was always lower than 8 and presented a large seasonal signal of 0.3 (high
705 pH values in spring, low in winter). The mean difference between calculated and measured pH-25C for 46
706 samples was equal to $+0.013$ (± 0.010) which is in the range of the pH uncertainty evaluated by error
707 propagation when calculated from A_T - C_T pairs (A_T - C_T error of $\pm 3 \mu\text{mol kg}^{-1}$ leads to pH error of ± 0.0144). Part
708 of these A_T - C_T data used to calculate pH also helped for interpreting the response of marine species to
709 acidification, e.g. pteropodes or coccolithophores (*Emiliana huxleyi*) in the Mediterranean Sea (Howes et al.,
710 2015, 2017; Meier et al., 2014) or in the Southern Ocean (Beaufort et al., 2011). The A_T - C_T data were also



711 supporting environmental analysis in coral reef ecosystems in the tropical Pacific (TARA Expedition, Douville
712 et al., 2022; Lombard et al., 2023; Canesi et al., 2023).

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714 4 Spatial distribution of A_T and C_T : a global view from the SNAPO-CO2 dataset

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716 The surface distribution in the global ocean based on the SNAPO-CO2 dataset is presented in Figure 7
717 for A_T and C_T . In the open ocean, high A_T concentrations are identified in the subtropics in all basins (Jiang et al.,
718 2014; Takahashi et al., 2014) with highest concentrations up to $2484 \mu\text{mol kg}^{-1}$ in the central North Atlantic
719 (STRASSE cruise in August 2012, $26^\circ\text{N}/36^\circ\text{W}$). In surface and at depth, the A_T /Salinity and A_T/C_T relationships
720 are clearly identified and structured at regional scale (Figure 8).

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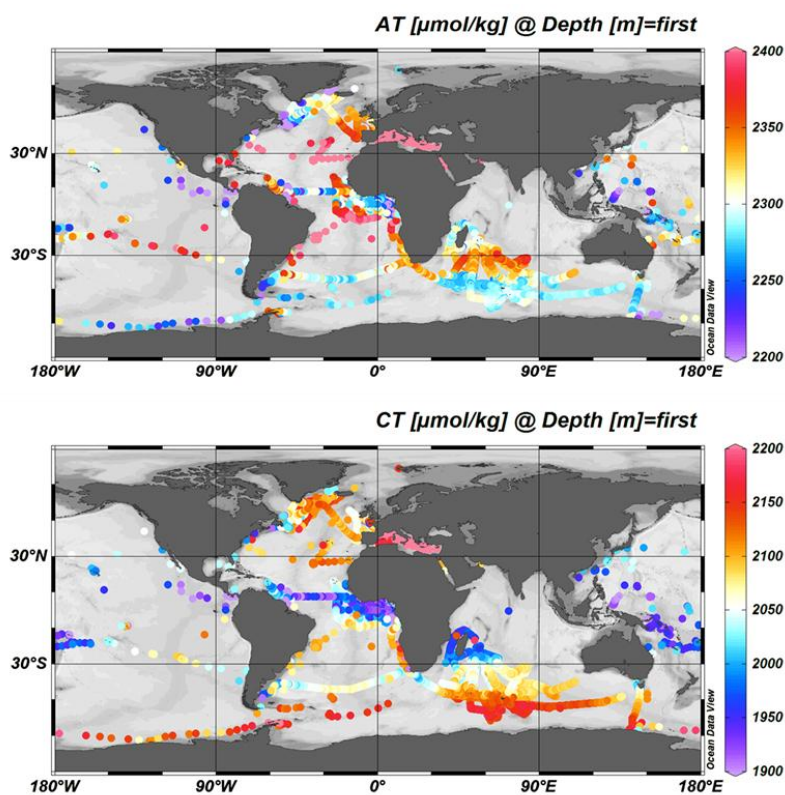
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750 **Figure 7:** Distribution of A_T (top) and C_T (bottom) concentrations ($\mu\text{mol.kg}^{-1}$) in surface waters (0-10m). Only
751 data with flag 2 are presented in these figures. Figures produced with ODV (Schlitzer, 2018).



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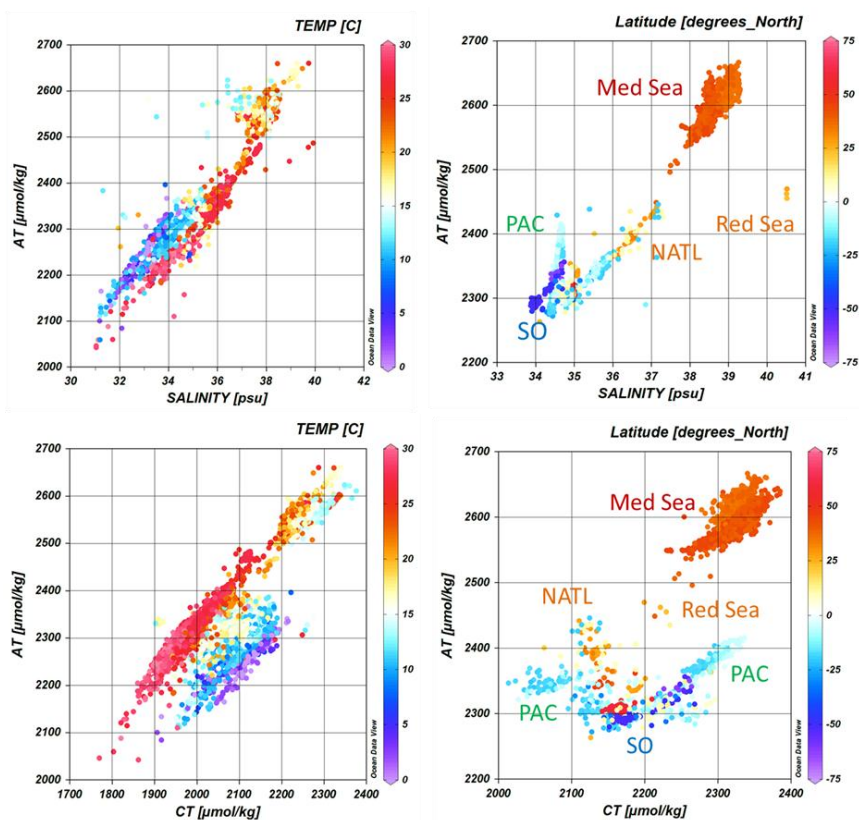


Figure 8: Relationships between A_T and Salinity (upper panel) and A_T versus C_T (lower panel) for samples in surface waters (0-10m and SSS > 31) (left) and in the water column below 100m (right). Only data with flag 2 are presented. The color scales correspond to the temperature (left) or the latitude (right). Some location of data are identified: Mediterranean Sea (Med Sea), Red Sea, Tropical Pacific (PAC), North Atlantic (NATL) and Southern Ocean (SO). Figures produced with ODV (Schlitzer, 2018).

In the eastern tropical Atlantic (ETA) where the Congo River impacts the salinity field (Vangriesheim et al., 2009), A_T concentrations range between 2100 and 2400 $\mu\text{mol kg}^{-1}$. The regional A_T /Salinity relationship in the ETA based on data from the EGEE cruises in 2005-2007 (Koffi et al., 2010) is robust and validated with more recent measurements from PIRATA-FR cruises in 2010-2019 (Lefevre et al., 2021). The strong A_T /Salinity relationship in the ETA was also recognized using data from the TARA-MICROBIOME cruise in May-July 2022 (Figure S7). Low salinity (< 30) and low A_T (1700-2200 $\mu\text{mol kg}^{-1}$) are also observed in the western tropical Atlantic near the Amazon River plume. The A_T /Salinity relationships in both river plume regions are very similar (Figure S7).

For C_T , the lowest concentrations were observed in the coastal regions of the Tropical Atlantic, on the eastern side in the Gulf of Guinea (BIOZAIRE cruise in 2003, 6°S/11°E, $C_T=1390 \mu\text{mol kg}^{-1}$, Vangriesheim et al., 2009) and on the western side in coastal zone off French Guyana (PLUMAND cruise in 2007, 5°N/51°W, $C_T=1512 \mu\text{mol kg}^{-1}$, Lefèvre et al., 2010). Such low C_T concentrations were also observed around 5°N/51°W in the Amazon River plume during the recent EUREC4A-OA cruise in 2020 and the TARA-MICROBIOME cruise in 2021 ($C_T=1451 \mu\text{mol kg}^{-1}$) leading to low oceanic $f\text{CO}_2$ (< 350 μatm) and a CO_2 sink in this region (Olivier et al., 2022).



809 The high C_T concentrations were mainly observed in the Southern Ocean (OISO and ACE cruises)
810 south of the Polar Front around 50°S linked to the upwelling of C_T -rich deep water (Figure 7, Metzl et al., 2006;
811 Wu et al., 2019; Chen et al., 2022). This leads to a high C_T/A_T ratio and a high Revelle factor in the Southern
812 Ocean (Figure 9, Fassbender et al., 2017). The high C_T content and low temperature in the Southern Ocean also
813 lead to low calcite and aragonite saturation state (Ω) (Takahashi et al., 2014; Jiang et al., 2015) but at present the
814 surface ocean is not under-saturated with regard to aragonite (Figure 10); however, under-saturation levels (Ω -
815 $\text{Ar}<1$) were found around 500 m in the Southern Ocean (ACE cruise in 2017, MODYDICK cruise in 2018),
816 1000 m in the Tropical Pacific (PANDORA 2012 and OUTPACE 2015 cruises) and 2200 m in the North
817 Atlantic (OVIDE 2012 and 2014 cruises, see also Turk et al., 2017) (Figure 10). Samples at 400 m from the
818 TARA-Oceans cruise in 2009-2012 also indicated aragonite under-saturation in the Equatorial Atlantic,
819 Equatorial Pacific, as well as off South America (73°W - 34°S , Chile) associated to equatorial or eastern boundary
820 upwelling systems (Feely et al., 2012; Lauvset et al., 2020).

821 In surface, Ω - $\text{Ar} >3$ is found in the latitudinal band 45°S - 54°N and Ω - $\text{Ar}<3$, below the critical
822 threshold of Ω - $\text{Ar}=3.25$ that represents a limit for distribution of tropical coral reefs (Hoegh-Guldberg et al.,
823 2007) is observed at very few locations in the tropics.

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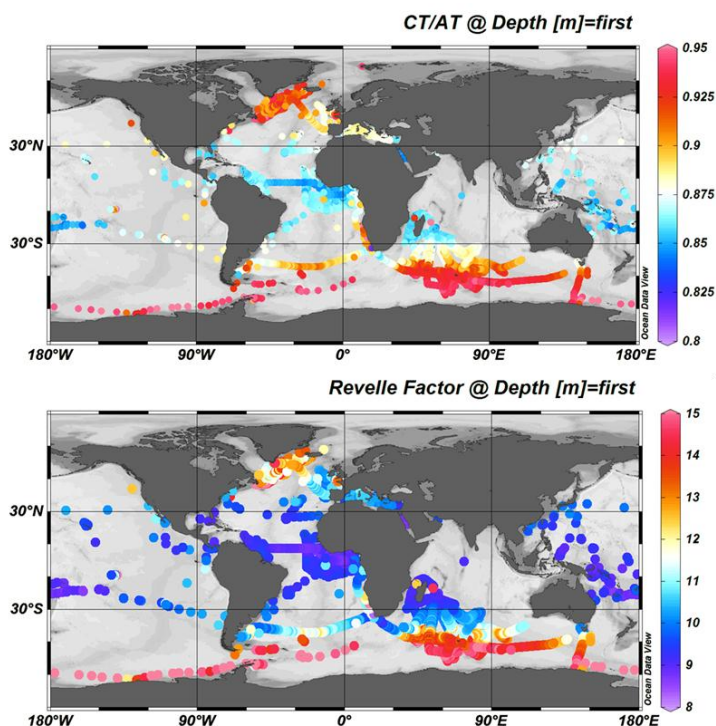
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845 **Figure 9:** Distribution of the C_T/A_T ratio (top) and the Revelle factor (bottom) in surface waters (0-10m). Only
846 data with flag 2 were used. Figures produced with ODV (Schlitzer, 2018).



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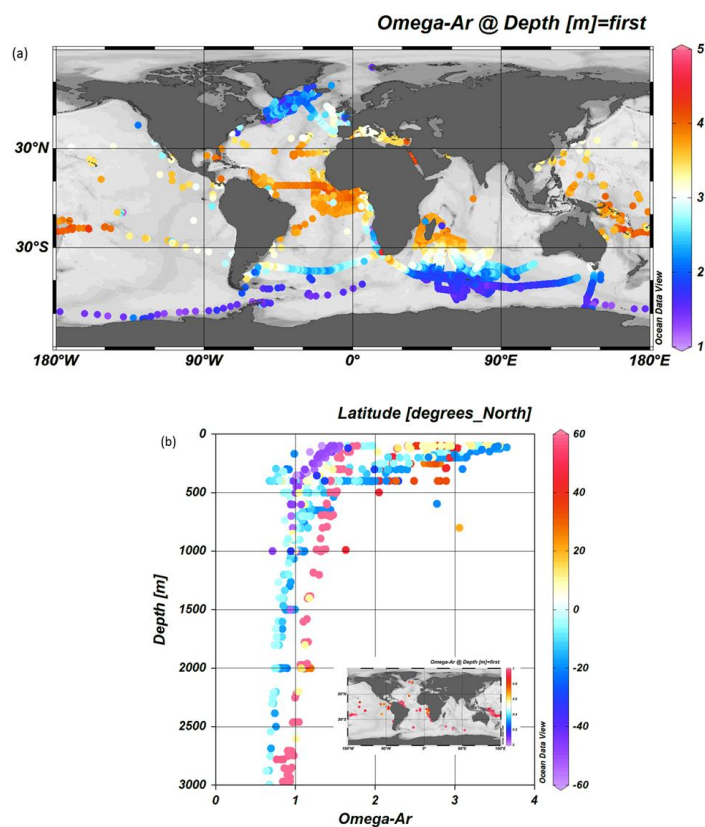


Figure 10: (a): Distribution of the aragonite saturation state (Ω -Ar) in surface waters (0-10m). Only data with flag 2 were used. (b): Depth profiles (100-3000m) of Ω -Ar at few locations in the Tropical Pacific, Atlantic and Southern Oceans. Stations where under-saturation is detected (Ω -Ar<1) at depth are identified in the inserted map. Figures produced with ODV (Schlitzer, 2018).

Compared to the open ocean, A_T concentrations are much higher in the Mediterranean Sea (Copin-Montégut, 1993; Schneider et al., 2007; Álvarez et al., 2023) with values up to 2600 $\mu\text{mol kg}^{-1}$ (Figure 8). The A_T and C_T data obtained in 1998-2019 show on average a clear contrast between the northern and southern regions of the western Mediterranean sea (Figure 11 a, b) with higher concentration in the Ligurian Sea and the Gulf of Lion (Gemayel et al., 2015). However, the basin scale average distribution view smoothed the meso-scale signals recognized in the Mediterranean Sea (e.g. Bosse et al., 2017; Petrenko et al., 2017). In the Gulf of Lion the synthesis of 11 cruises conducted from May 2010 to June 2011 (CARBORHONE, CASCADE, LATEX, MOLA, MOOSE-GE) highlights the contrasting distributions of A_T and C_T in the coastal zones and off shore (Figure 11 c, d). The averaging of all data in 1998-2019 also smoothed the seasonal signal and the inter-annual variability described below.



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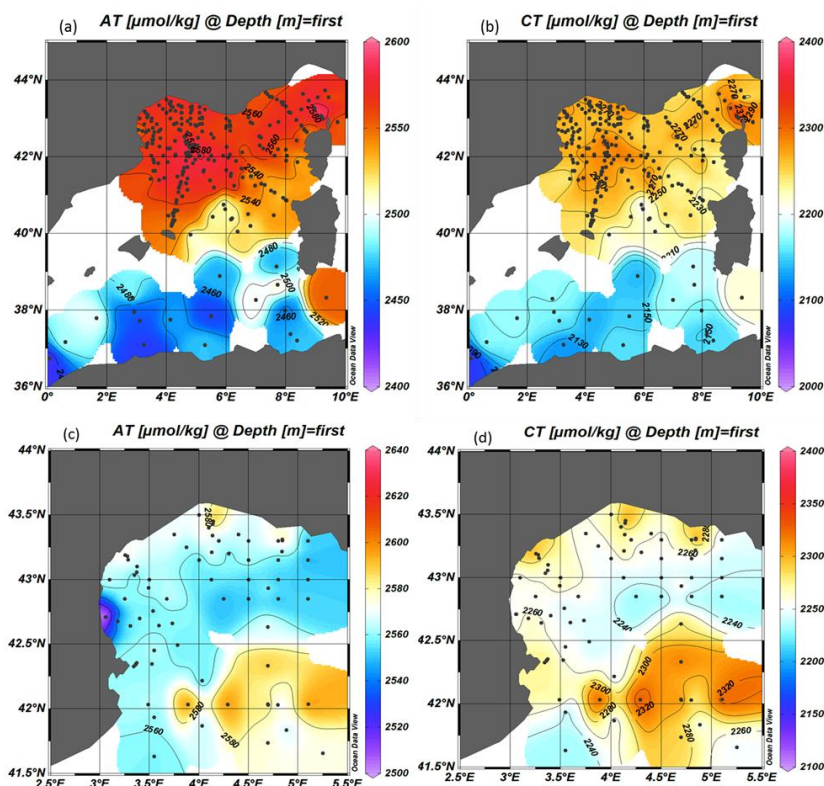


Figure 11: Distribution of A_T (a) and C_T (b) in $\mu\text{mol.kg}^{-1}$ in surface waters of the western Mediterranean Sea (0-10m) from all data for 1998-2019. Detailed distribution of A_T (c) and C_T (d) in $\mu\text{mol.kg}^{-1}$ in surface waters of the Gulf of Lion for the period 2010-2011 only (cruises CARBORHONE, CASCADE, LATEX, MOLA, MOOSE-GE). Figures produced with ODV (Schlitzer, 2018).

5 Temporal variations of A_T and C_T : examples from the SNAPO-CO2 dataset

Time-series stations such as BATS, ESTOC, HOT, in the Irminger Sea or in the Iceland Sea are the only way to detect the long-term change in the ocean carbonate system in the surface and the water column (Bates et al., 2014). These important time-series help to understand driving processes (e.g. Hagens and Middelburg, 2016) and are often used to validate the $p\text{CO}_2$, A_T , C_T , or pH reconstructed fields (e.g. Rödenbeck et al., 2013; Broullón et al., 2019, 2020; Keppler et al., 2020; Gregor and Gruber, 2021; Chau et al., 2023; Ma et al., 2023).

Here we show examples of the temporal surface variations at locations where data were obtained for more than 10 years (Figure 12). We thus selected the following contrasting regions: the North Atlantic Subpolar Gyre (NASPG around $60^\circ\text{N}/30^\circ\text{W}$, period 1993-2018), the Equatorial Atlantic (at $2^\circ\text{N}-2^\circ\text{S}/12^\circ\text{W}-8^\circ\text{W}$, period 2005-2017), the Indian Ocean subtropical sector ($26-35^\circ\text{S}/50-56^\circ\text{E}$, period 1998-2018), the Indian Ocean high latitude ($54-60^\circ\text{S}/60-70^\circ\text{E}$, period 1998-2018), the Ligurian Sea (around DYFAMED station, $43.5-42.5^\circ\text{N}/5.5-9^\circ\text{E}$, period 1998-2019) and times-series stations in the coastal zones off Brittany (period 2008-2019).



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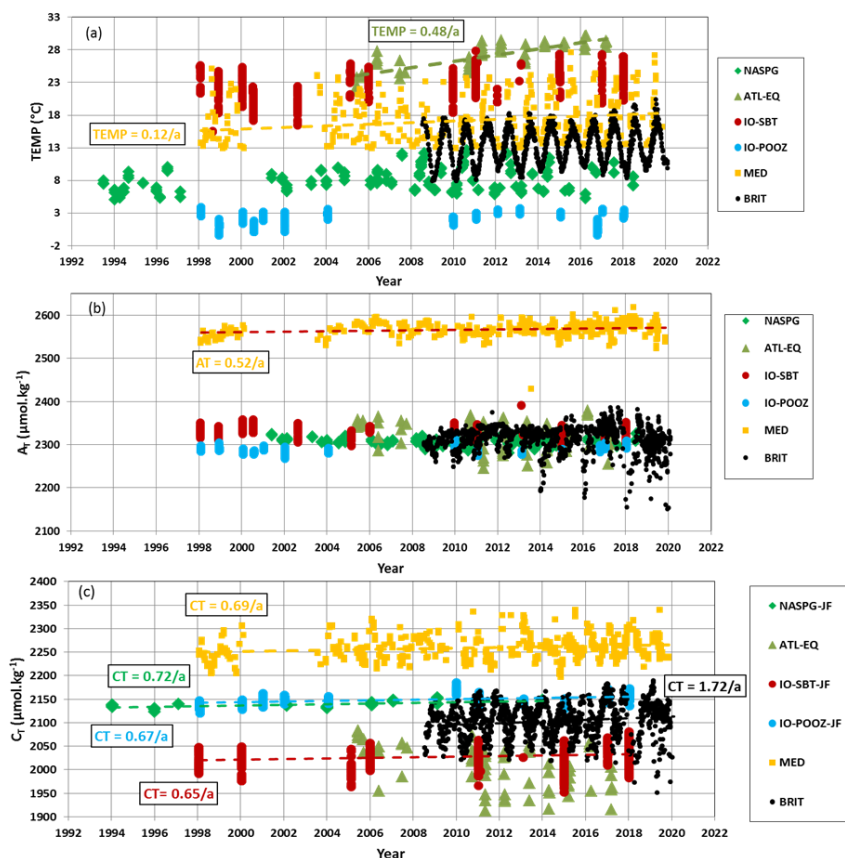


Figure 12: Time-series of (a) sea surface temperature ($^{\circ}\text{C}$), (b) A_T ($\mu\text{mol.kg}^{-1}$) and (c) C_T ($\mu\text{mol.kg}^{-1}$) in 6 regions: the North Atlantic Subpolar Gyre (NASPG 1993-2018, green diamond), the Equatorial Atlantic (ATL-EQ, 2005-2017, green triangle), the Indian subtropical sector (IO-SBT, red circle) and high latitude (IO-POOZ, blue circle) (1998-2018), the Ligurian Sea (MED, 1998-2019, orange square) and times-series stations in the coastal zones off Brittany (BRIT, period 2008-2019, black dots). Trends (dashed lines) are shown when relevant for the discussion (C_T trends listed in Table 6).

Table 6: Trend of C_T ($\mu\text{mol kg}^{-1} \text{ yr}^{-1}$) and corresponding standard error in 5 selected regions where data were available for more than 10 years (data are shown in Figure 12). The projects/cruises for selection of the data in each domain are indicated.

Region	Period	C_T trend $\mu\text{mol kg}^{-1} \text{ yr}^{-1}$	Season	Projects/Cruises
NASPG	1994-2014	+0.719 (0.168)	Jan-Feb	SURATLANT
Indian SBT	1998-2018	+0.646 (0.117)	Jan-Feb	OISO
Indian High Lat	1998-2018	+0.668 (0.042)	Jan-Feb	OISO
Ligurian Sea	1998-2019	+0.686 (0.181)	All seasons	DYFAMED, BOUSSOLE, MOOSE-GE
Coast Brittany	2008-2019	+1.720 (0.281)	All seasons	Brest, Roscoff, ECOSCOPIA, PENZE

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987 In the 6 regions, there was a progressive warming most clearly detected in the Mediterranean Sea (e.g.
988 Nykjaer, 2009). From 1998 to 2019 the warming in the Ligurian Sea was $+0.1208^{\circ}\text{C yr}^{-1}$ (± 0.0227) (Figure 12).
989 In the equatorial Atlantic, the apparent rapid increase of temperature of $+0.48^{\circ}\text{C yr}^{-1}$ (± 0.04) in 2005-2017 from
990 the selected data indicated a change in water masses and circulation. The colder sea surface in 2005 was
991 associated with the so-called Atlantic Cold Tongue (ACT) which was one of the most intense ATC since 1982
992 (Caniaux et al., 2011). The ACT also leads to significant changes in oceanic $f\text{CO}_2$ and air-sea CO_2 fluxes (Parard
993 et al., 2010; Koseki et al., 2023) and explained the high C_T concentrations observed in 2005 in this region
994 (Figure 12, Koffi et al., 2010).

995 Alkalinity presents rather homogenous concentrations in the NASGP and the south Indian Ocean. Inter-
996 annual variability of A_T is pronounced in the equatorial Atlantic ranging between 2245 and 2378 $\mu\text{mol kg}^{-1}$. This
997 is mainly related to salinity as normalized A_T values ($N-A_T$, for salinity= 35) do not show such inter-annual
998 variability (Mean $N-A_T = 2295.7 \pm 4.6 \mu\text{mol kg}^{-1}$, $n = 67$ for 2005-2017, not shown). In the coastal zones off
999 Brittany, the A_T is also highly variable (Salt et al., 2016; Gac et al., 2021) ranging between 2150 and 2386 μmol
1000 kg^{-1} (Figure 12).

1001 An interesting signal is the progressive increase of A_T in the Mediterranean Sea. The positive A_T trend
1002 of $+0.53$ (± 0.11) $\mu\text{mol kg}^{-1} \text{ yr}^{-1}$ ($n=538$) in 1998-2019 in the region offshore was also observed at the coastal
1003 station SOMLIT-Point-B in 2007-2015 but with a faster increase of $+2.08$ (± 0.19) $\mu\text{mol kg}^{-1} \text{ yr}^{-1}$ (Kapsenberg et
1004 al., 2017). Close to the DYFAMED site, at station SOMLIT-Point-B, the A_T trend was not linked to salinity
1005 temporal changes as a positive $N-A_T$ trend was also reported, $+0.52$ (± 0.07) $\mu\text{mol kg}^{-1} \text{ yr}^{-1}$ (not shown). Based
1006 on data from the PERLE cruises in 2018-2021 a significant increase in A_T was also identified in the Eastern
1007 Mediterranean Sea (Wimart-Rousseau et al., 2021). Along with the increase of C_T and the warming, the A_T
1008 increase would impact on the $f\text{CO}_2$, air-sea CO_2 fluxes and pH temporal changes (Merlivat et al., 2018).
1009 Processes explaining the A_T increase in the Mediterranean Sea are still unexplained and deserve further
1010 investigations (Coppola et al., 2019).

1011 As expected, because of the anthropogenic CO_2 uptake the C_T concentrations increased in most regions
1012 (Figure 12, Table 6). This is identified in the Indian Ocean (in the subtropics and the high latitude), in the
1013 Mediterranean Sea, and in coastal waters off Brittany. However, the signal is more complex in the NASPG. As
1014 previously shown the C_T trend in the NASPG depends on seasons and decades (Metzl et al., 2010; Reverdin et
1015 al., 2018; Fröb et al., 2019; Leseurre et al., 2020). Here we selected only the data in January-February from the
1016 SURATLANT cruises leading a C_T trend of $+0.719$ (± 0.168) $\mu\text{mol kg}^{-1} \text{ yr}^{-1}$. Compared to the regions further
1017 north the C_T trend in the NASPG is about half the C_T trends of $+1.44$ (± 0.23) $\mu\text{mol kg}^{-1} \text{ yr}^{-1}$ observed in the
1018 Iceland Sea (Olafsson et al., 2009) or $+1.48$ (± 0.22) $\mu\text{mol kg}^{-1} \text{ yr}^{-1}$ at station M in the Norwegian Sea (Skjelvan
1019 et al., 2022).

1020 In the coastal zones off Brittany, although there are large seasonal and inter-annual variabilities (Gac et
1021 al., 2021), an annual C_T trend of $+1.72$ (± 0.28) $\mu\text{mol kg}^{-1} \text{ yr}^{-1}$ is detected over 10 years (2009 to 2019). The same
1022 is observed in the Mediterranean Sea where the C_T offshore trend of $+0.69$ (± 0.18) $\mu\text{mol kg}^{-1} \text{ yr}^{-1}$ is low
1023 compared to what was observed in the coastal zone (SOMLIT-Point-B, $+2.97$ (± 0.20) $\mu\text{mol kg}^{-1} \text{ yr}^{-1}$, Kapsenberg
1024 et al., 2017).

1025 In the southern Indian Ocean, C_T concentrations also increased in both subtropical and high latitudes,
1026 two regions where the primary productivity is relatively low (oligotrophic regime in the subtropics and High
1027 Nutrient Low Chlorophyll regime, HNLC, south of the Polar Front). With the data selected for austral summer



1028 (January-February) the C_T trends appeared almost similar in these two regions, around $+0.65 \mu\text{mol kg}^{-1} \text{yr}^{-1}$
1029 (Table 6).

1030 Finally, in the Equatorial Atlantic the selected data around 0° - 10°W highlighted the large variability
1031 linked to the oceanic circulation. Detecting a C_T trend as well as a possible link with anthropogenic carbon
1032 uptake, at least with the data available in 2005-2017, appears to be intricate as it has been previously discussed
1033 for the period 2006-2013 (Lefèvre et al., 2016). However, the signal of the C_T increase is better identified north
1034 or south of the Equator in the eastern tropical Atlantic sector (Lefèvre et al., 2021).

1035 In the water column A_T - C_T data from dedicated cruises were used to evaluate the C_{ant} distribution and
1036 pH change since pre-industrial era (e.g. PANDORA cruise, Ganachaud et al., 2017; OUTPACE cruise, Wagener
1037 et al., 2018; SOMBA cruise, Keraghel et al., 2020). Time-series at DYFAMED station also enabled to
1038 investigate the temporal variability of C_T , A_T and C_{ant} in the water column (Touratier and Goyet, 2009; Coppola
1039 et al., 2020; Fourrier et al., 2022). As an example of the observed temporal variations at depth we selected the
1040 data in the layer 950-1050m in the Ligurian Sea from different cruises (Figure 13). At that depth both A_T and C_T
1041 present some large anomalies especially noticed in 2013 (lower A_T and C_T in February 2013, DEWEX cruise)
1042 and in 2018 (lower A_T and C_T in May 2018, MOOSE-GE cruise) the later probably linked to episodic convective
1043 process that occurred in winter 2018 (Fourrier et al., 2022). In this region the long-term increase of A_T indicates
1044 that in addition to the anthropogenic CO_2 signal another process is at play to explain the rapid C_T trend of $+1.20$
1045 (± 0.12) $\mu\text{mol kg}^{-1} \text{yr}^{-1}$ at depth compared to that observed in surface (Figure 12). The signal at depth is probably
1046 linked to the variations of the deep convection and mixing with Levantine intermediate water (LIW, Margirier et
1047 al., 2020) with higher A_T and C_T concentrations. The long-term increase of A_T and C_T at depth (here at 1000m,
1048 Figure 13) was also observed below 2000m (Coppola et al., 2020) a signal that has to be investigated in
1049 dedicated analysis using other properties (O_2 , nutrients, following Fourrier et al. (2022) for the period 2012-
1050 2020) and a larger dataset in the Mediterranean Sea (e.g. CARIMED).

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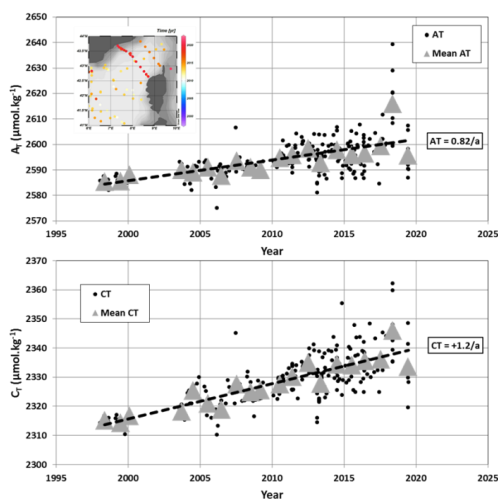


Figure 13: Time-series of A_T ($\mu\text{mol.kg}^{-1}$) and C_T ($\mu\text{mol.kg}^{-1}$) in the Ligurian Sea (1998-2019) in the layer 950-1050m. Annual mean (grey triangles) was calculated from all data each year (black dots). The trends (dashed line) based on annual mean are $+0.82$ (± 0.15) $\mu\text{mol.kg}^{-1}.\text{yr}^{-1}$ for A_T and $+1.20$ (± 0.12) $\mu\text{mol.kg}^{-1}.\text{yr}^{-1}$ for C_T . In this layer data selected are from cruises ANTARES, CASCADE, DEWEX, DYFAMED, MOOSE-GE and PEACETIME (location of stations shown in the inserted map).



1075 **6 Using A_T and C_T data to validate observations from autonomous instruments**

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1077 The dataset presented in this synthesis would also offer interesting observations to validate properties
1078 (A_T and C_T) derived from **BG**-ARGO floats equipped with pH sensors (e.g. Bushinsky et al., 2019; Mazloff et
1079 al., 2023; Mignot et al., 2023). The water column in situ A_T - C_T data obtained during the Antarctic Circumpolar
1080 Expedition (ACE) in 2016-2017 were collected at location where SOCCOM floats were launched (Walton and
1081 Thomas, 2018). A SOCCOM float (WMO ID 5905069) was launched on January 11th 2017 at 55°S-96°E south
1082 of the Polar Front in the southern Indian Ocean. The pH, temperature and salinity data from the float were then
1083 used to derive A_T and C_T profiles (here using the MLR method, Williams et al., 2016, 2017). In the top layers the
1084 discrete ACE data (Figure 14) present large variability of A_T and C_T concentrations not captured in the records
1085 derived from the float (MLR method somehow smooth the profiles). However, given the uncertainty in
1086 reconstructed A_T from float data ($5.6 \mu\text{mol kg}^{-1}$) the average values in the first 100m were almost identical (A_T -
1087 $_{ACE} = 2285.1 (\pm 4.4) \mu\text{mol kg}^{-1}$ and A_T - $_{float} = 2278.3 (\pm 0.7) \mu\text{mol kg}^{-1}$; C_T - $_{ACE} = 2139.7 (\pm 9.2) \mu\text{mol kg}^{-1}$ and C_T -
1088 $_{float} = 2141.1 (\pm 3.2) \mu\text{mol kg}^{-1}$). Moreover below 200m, profiles from the float are coherent compared to the A_T -
1089 C_T measurements (Figure 14). This is encouraging for using float data to explore the seasonal variability of A_T
1090 and C_T in the Southern Ocean (e.g. Williams et al., 2018; Johnson et al., 2022) and the estimation of
1091 anthropogenic CO_2 in the water column in this sector (Figure 14). Here the C_{ant} concentrations were calculated
1092 below 200m (corresponding to the temperature minimum of the winter in the SO and using the TrOCA
1093 method, Touratier et al., 2007). The float data suggest that C_{ant} concentrations are positive down to about 1000m,
1094 with maximum values in subsurface. In 2017 the mean C_{ant} concentration at 200m was $49.1 (\pm 9.0) \mu\text{mol kg}^{-1}$.
1095 Below that depth, C_{ant} decreased and reduced to $+29.8 (\pm 8.5) \mu\text{mol kg}^{-1}$ in the layer 300-400m. To complement
1096 the C_{ant} inventories based on GLODAP data-product (e.g. Gruber et al., 2019) C_{ant} estimates derived from BG-
1097 ARGO floats as evaluated here in the Southern Ocean could be applied in other locations as was previously
1098 tested in the North Pacific (Li et al., 2019).

1099 In surface water as the A_T derived from the float data are deduced using MLR or LIAR methods
1100 (Williams et al., 2017; Carter et al., 2016), the A_T data in the SNAPO-CO₂ synthesis could also be used to
1101 identify A_T anomalies not always captured from floats. This is particularly relevant in coccolithophores blooms
1102 areas when low A_T concentrations and high pCO₂ are observed (e.g. Balch et al., 2016 in the Southern Ocean;
1103 Robertson et al., 1994 in the North Atlantic).

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1105 **7 Summary and suggestions**

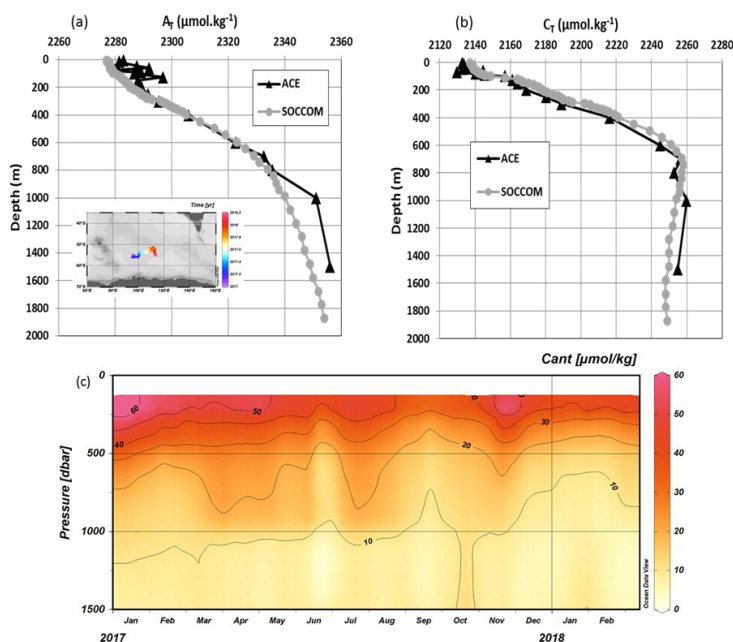
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1107 The ocean data synthesized in this product are based on measurements of A_T and C_T performed **in** 1993-
1108 2022 with an accuracy of $\pm 4 \mu\text{mol kg}^{-1}$. It offers a large data set of A_T and C_T for the global ocean and regional
1109 biogeochemical studies. It includes more than 44 400 surface and water column observations in all oceanic
1110 basins, in the Mediterranean Sea, in the coastal zones, near coral reef, and in rivers. For the open ocean this
1111 complements the SOCAT and GLODAP data-products (Bakker et al., 2016; Lauvset et al., 2021) **and for the**
1112 **Mediterranean Sea the ongoing CARIMED dataset**. For the coastal sites this also complements the synthesis of
1113 coastal time-series only done around North America (Fassbender et al., 2018; Jiang et al., 2020; OCADS, 2023).

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1134 **Figure 14:** Profiles of (a) A_T ($\mu\text{mol.kg}^{-1}$) and (b) C_T ($\mu\text{mol.kg}^{-1}$) observed at station ACE-20 (55°S-95°E,
1135 11/1/17, black triangles) compared with the profiles deduced from the SOCCOM float (WMO code 5905069)
1136 launched at that location (first data on January 12th 2017, grey circles). The location/drift of the float in 2017-
1137 2018 is shown on the inserted map. (c) Hovmöller section (Pressure/time) of anthropogenic CO₂ concentrations
1138 (C_{ant} in $\mu\text{mol.kg}^{-1}$) estimated from the float data (A_T , C_T , O₂, T) below 200m (period January 2017-February
1139 2018). Section produced with ODV (Schlitzer, 2018).
1140

1141 The SNAPO-CO₂ dataset enables to investigate seasonal variations to decadal trends of A_T and C_T in
1142 various oceanic provinces. In regions where data are available for more than 2 decades in surface water (North
1143 Atlantic, Ligurian Sea, Southern Indian Ocean, and coastal regions), all time-series show an increase in C_T .
1144 Excepted in the Mediterranean Sea, A_T appears relatively constant over time, although the A_T content present
1145 significant inter-annual variability such as in the NASPG or in the coastal zones including near the Congo and
1146 Amazon Rivers plumes.

1147 This dataset represents independent data for validation of reconstructed A_T or C_T fields using various
1148 methods (e.g. Rödenbeck et al., 2013, 2015; Sauzède et al., 2017; Turk et al., 2017; Bittig et al., 2018; Broullón
1149 et al., 2019, 2020; Land et al., 2019; Keppler et al., 2020; Fourier et al., 2020; Gregor and Gruber, 2021; Sims et
1150 al., 2023; Chau et al., 2023). It is also useful to validate Earth System Models (ESM) that currently present bias
1151 to reproduce the seasonal cycle of C_T and A_T due to inadequate representation of biogeochemical cycles,
1152 including the coupling of biological and physical processes (e.g. Pilcher et al., 2015; Mongwe et al., 2018;
1153 Lerner et al., 2021). This should be resolved for confident in future projections of the productivity, ocean
1154 acidification, and the responses of the marine ecosystems (e.g. Kwiatowkki et al., 2020). Recall that OBG or
1155 ESM models calculate pCO₂ from A_T - C_T pairs and the simulated annual CO₂ flux might be correct when
1156 compared to observations but for wrong reasons (e.g. Goris et al., 2018, Lerner et al., 2021). For example, it has
1157 been shown that biases in A_T in ESM models led to an overestimation of the oceanic fCO₂ trend and thus
1158 uncertainty when predicting the oceanic anthropogenic CO₂ uptake (Lebehot et al., 2019). The simulated



1159 seasonal cycle of $p\text{CO}_2$ is also uncertain in ESM models especially in high latitudes (e.g. Joos et al., 2023). It is
1160 thus important to attempt validating ESM models with A_T - C_T data such as presented in this synthesis.

1161 This dataset would also serve for validating autonomous platforms capable of measuring pH and $p\text{CO}_2$
1162 variables and, along with SOCAT and GLODAP datasets, provides an additional reference dataset for the
1163 development and validation of regional biogeochemical models for simulating air-sea CO_2 fluxes. It is also
1164 essential for training and validating neural networks capable of predicting variables in the carbonate system,
1165 thereby enhancing observations of marine CO_2 at different spatial and temporal scales.

1166 The data presented here are available online on the Seanoë server (Metzl et al., 2023,
1167 <https://doi.org/10.17882/95414>) and is divided in two files: one for the Global Ocean, and one for the
1168 Mediterranean Sea. The sources of the original datasets (doi) with the associated references are listed in the
1169 Supplementary Material (Table S3, S4). We invite the users to comment on any anomaly that would have not
1170 been detected or to suggest potential misqualification of data in the present product (e.g. data probably good
1171 although assigned with Flag 3, probably wrong). The SNAPO- CO_2 dataset will be regularly updated on Seanoë
1172 data server with new observations controlled and archived.

1173

1174 **8 Data availability**

1175 Data presented in this study are available at Seanoë: <https://www.seanoë.org>, <https://doi.org/10.17882/95414>
1176 (Metzl et al., 2023).

1177

1178 *Author contributions.* NM prepared the data synthesis, the figures and wrote the draft of the manuscript with
1179 contributions from all authors. JF measured the discrete samples since 2014, with the help from CM and CLM,
1180 and prepared the individual reports for each project. NM and JF pre-qualified the discrete A_T - C_T data. CLM and
1181 NM are co-Is of the ongoing OISO project and qualified the underway A_T - C_T data from OISO cruises. All
1182 authors have contributed either to organizing cruises, sample collection or data qualification.

1183

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1185

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1215

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