



Quality Information Document

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Copernicus Marine Environment Monitoring
Service

Global surface ocean pH trends

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I INTRODUCTION

I.1 Product name

GLOBAL_OMI_HEALTH_carbon_ph_trend

I.2 Indicator evaluation method

Secular trends and the associated uncertainties ($\pm 1\sigma$) of seawater pH over the global surface ocean are computed from the 100-member ensemble of pH time series. This ensemble covering the period since 1985 was randomly regenerated with a Gaussian distribution where the mean and the standard deviation are, respectively, the best estimate and the total uncertainty of pH available in the Surface Carbon field **MULTIOBS_GLO_BIO_CARBON_SURFACE_REP_015_008** (Chau et al., 2021). Surface ocean pH is reported on total scale and the units of its trend and uncertainty are yr^{-1} .

Denote μ_{ij} and σ_{ij} as a linear trend and its uncertainty computed from a batch of 100 yearly mean pH time series ($\text{pH}_{t,ij,n}$) at each $1^\circ \times 1^\circ$ -grid cell ij , where t stands for time and n indicates a member in the 100-member ensemble. A linear least-squares regression was used to fit a linear function between two sets of data (i.e., $\text{pH}_{t,ij,n}$ against t values) and derive estimates of its slope (μ_{ij}) and residual standard deviation (σ_{ij}). An illustration of the method of linear fits on the pH data at some stations is shown in Figure 1.

The global maps of pH trend and uncertainty are presented in Figure 2 (a,b). A threshold on σ of 0.0003 yr^{-1} is empirically defined to mask the regions with uncertain estimates of pH local trend (Figure 2c). The global pH trend map and this mask are reproduced in Figure 3 - a representative map for this new OMI for surface ocean pH trend.

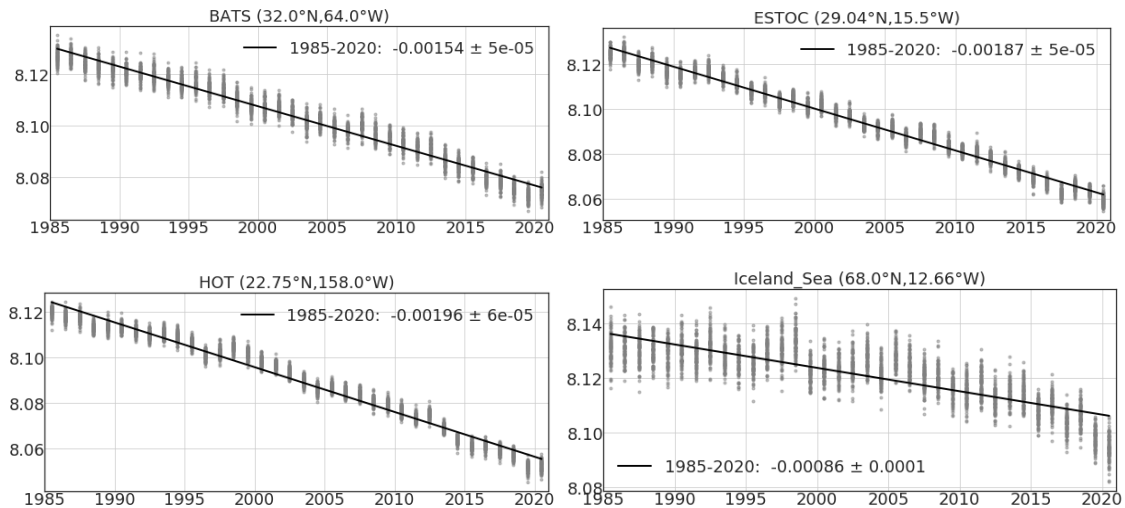


Figure 1. Linear fits on the 100-member ensemble of yearly mean pH at different stations (see also in Table 1). Grey points represent pH data in the ensemble and black lines stand for their linear fits. $\mu_{ij} \pm \sigma_{ij}$ denotes estimates of a linear slope and its uncertainty over 1985-2020.

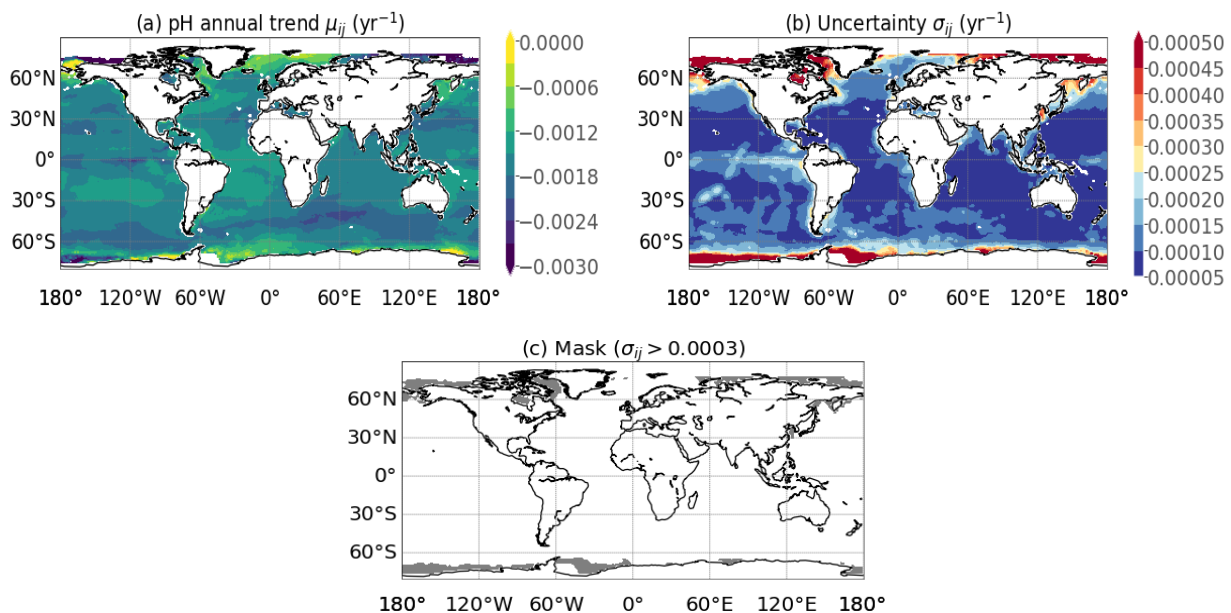


Figure 2. (a) Global surface seawater pH trend and (b) uncertainty computed over the period 1985-2020. (c) Mask of the regions where uncertainty estimates of local trends exceed 0.0003 yr^{-1} .



I.3 CMEMS products used as input for the computations

| Product name (and Type) | Documentation |
|---|---|
| MULTIOBS_GLO_BIO_CARBON_SURFACE_REP_015_008 | QUID: https://catalogue.marine.copernicus.eu/documents/QUID/CMEMS-MOB-QUID-015-008.pdf PUM: https://catalogue.marine.copernicus.eu/documents/PUM/CMEMS-MOB-PUM-015-008.pdf |

II SCIENTIFIC EVALUATION

For the period since 1985 pH is decreasing at a rate between -0.0008 yr^{-1} and -0.0022 yr^{-1} over most of the global ocean basins (Figure 3). The spatial pattern of pH secular trends is generally consistent with that presented in Lauvset et al (2015). Nearly all values of the trend exceed the associated uncertainty estimate (Figure 2b) but we conservatively exclude the ones associated with the largest uncertainty estimates (Figures 2c), knowing that they may be underestimated. Only a portion of data over some sectors of the Arctic and Antarctic has been masked indicating that there might be no certain estimates of pH trend (Figure 3).

Table 1 shows a comparison between the new OMI pH trends and those derived from pH speciation or measurements at 7 stations presented in Bates et al (2014). The location of these time series stations is plotted in Figure 4. The CMEMS OMI trend at each location is computed from monthly pH time series in the **MULTIOBS_GLO_BIO_CARBON_SURFACE_REP_015_008** dataset at the four grid boxes nearby. As seen in Table 1, the CMEMS OMI trend identified by for HOTS ($-0.0018 \pm 0.0001 \text{ yr}^{-1}$), BATS ($-0.0014 \pm 0.0001 \text{ yr}^{-1}$), and ESTOC ($-0.0018 \pm 0.0001 \text{ yr}^{-1}$) are in close agreement with those computed from observations in the previous studies (Dore et al., 2009; Gonzalez-Davila et al., 2010; Bates et al., 2014). Our estimate of pH trend at Irminger for 1985-2012 is about $-0.0014 \pm 0.0001 \text{ yr}^{-1}$ which is nearly twice as small as that by Bates et al 2014 but falls within the full range ($\pm 3\sigma$) of the estimate by Pérez et al (2021) for 1983-2013 ($-0.0017 \pm 0.00019 \text{ yr}^{-1}$). The magnitude of pH trend computed here for Iceland Sea [Mudina] is smaller [larger] than reported in Bates et al (2014). However, because of the low sampling frequency the comparison should be viewed with caution. CARIACO is located on the east coast of South America, its four nearest model grid boxes with available CMEMS pH data result in an average latitude with an offset of approximately 2° from this station and thus a mismatch from the estimate by Bates et al 2014 is expected (Table 1).

Overall, secular trends of seawater pH over the global surface ocean have a complex spatial pattern and their estimates are sensitive to physical and carbonate variables fed in pH speciation (Lauvset et al., 2015; Pérez et al., 2021). Up to present, direct measurements of surface ocean pH are still sparse (Bates et al., 2014; Lauvset et al., 2021), an increase in the observational networks for pH

and other carbonate variables is important for understanding and analyzing changes in seawater pH as well as for a better evaluation of their estimates (Lauvset et al., 2015).

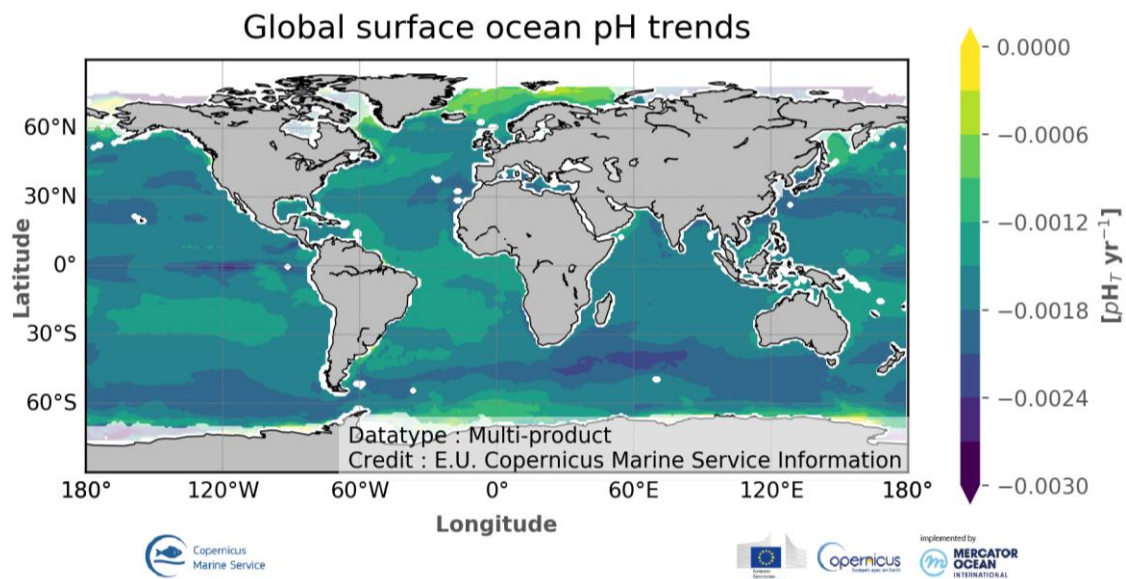


Figure 3. Global map of pH trend over the period 1985-2020. The white mask indicates the regions where pH trends with the highest uncertainty estimates are excluded (see indicator evaluation method).

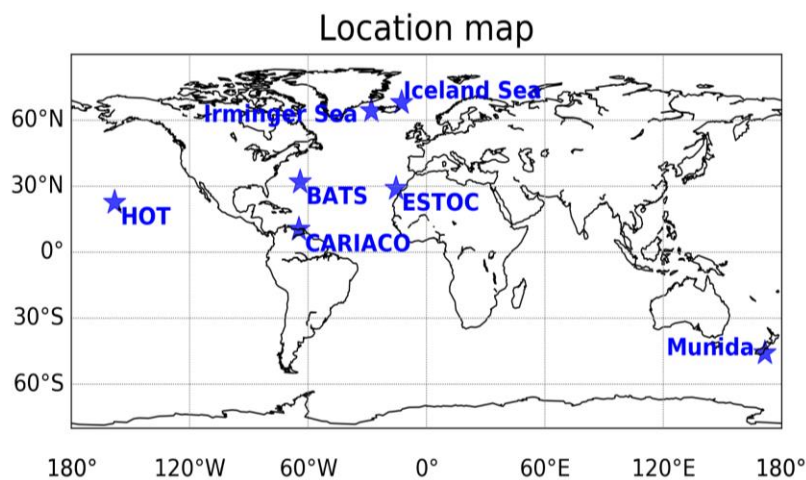


Figure 4. Location of seven time-series stations recording pH and carbonate variables (Bates et al., 2014).

Table 1: Comparison in surface ocean pH trend estimates for the seven time-series stations (Bates et al., 2014). Uncertainty is reported as $\pm 1\sigma$. The CMEMS OMI trend at each station is computed by learning on monthly pH time series in the MULTIOBS_GLO_BIO_CARBON_SURFACE_REP_015_008 dataset at the four grid boxes nearby.

| Data | Stations | Iceland Sea | Irminger Sea | BATS | ESTOC | HOT | CARIACO | Munida |
|--|-------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|---------------------------------|---------------------------------|-----------------------------------|
| Bates et al. 2014 | Years | 1983 – 2012 | 1983 – 2012 | 1983 – 2012 | 1995 – 2012 | 1988 – 2012 | 1995 – 2012 | 1998 – 2012 |
| | Latitude, Longitude | 68°N, 12.66°W | 64.3°N, 28°W | 32°N, 64°W | 29.04°N, 15.50°W | 22.75°N, 158°W | 10.5°N, 64.66°W | 45.7°S, 171.5°E |
| | Sampling frequency (per year) | 3–4 | 3–4 | 14–16 | 4–6 | 10 | 12 | ~ 4–6 |
| | pH trend (pH data type) | -0.0014 \pm 0.0005 (calculated) | -0.0026 \pm 0.0006 (calculated) | -0.0017 \pm 0.0001 (calculated) | -0.0018 \pm 0.0002 (calculated) | -0.0016 \pm 0.0001 (measured) | -0.0025 \pm 0.0004 (measured) | -0.0013 \pm 0.0003 (calculated) |
| CMEMS-OMI-QUID-GLO-HEALTH-carbon-ph-trend | Years | 1985 – 2012 | 1985 – 2012 | 1985 – 2012 | 1995 – 2012 | 1988– 2012 | 1995 – 2012 | 1998 – 2012 |
| | Latitude, Longitude | 68°N, 13°W | 64°N, 28°W | 32°N, 64°W | 29°N, 15°W | 23°N, 158°W | 12.5°N, 65°W | 46.5°S, 172°E |
| | pH trend | -0.0006 \pm 0.0001 | -0.0014 \pm 0.0001 | -0.0014 \pm 0.0001 | -0.0018 \pm 0.0001 | -0.0018 \pm 0.0001 | -0.0015 \pm 0.0001 | -0.0020 \pm 0.0002 |

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