

1 Upper Ocean O₂ trends: 1958-2015

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Table S1. O₂ trend and O₂-heat relationship The linear trend of O₂ inventories are calculated for the depth ranges of 0-100m, 100-200m, 200-400m, 400-700m, 700-1000m, and 0-1000m for the time period of 1958 to 2015. O₂-heat relationships are calculated by the linear regression for the same depth ranges. The uncertainties are based on one standard error. The units for the O₂ trend is 10¹²mol yr⁻¹ or Tmol yr⁻¹. The units for the regression coefficient are nmol O₂ J⁻¹.

Depth range	Linear trend	O₂-heat ratio
0-100m	-1.96 ± 1.27	-1.82 ± 0.40
100-200m	-3.30 ± 0.96	-5.43 ± 0.81
200-400m	-7.24 ± 2.42	-8.35 ± 0.74
400-700m	-7.21 ± 4.11	-10.7 ± 1.06
700-1,000m	-4.60 ± 2.07	-9.63 ± 0.90
0-1,000m	-24.3 ± 12.4	-8.20 ± 0.66

Figure S1. Temporal data coverage shows the geographic distribution of monitoring frequency. The resolution is 1x1 degree in longitude-latitude grid. Temporal data coverage is calculated by counting the number of annually binned observed O₂ data for the period of 1958-2015 in each grid cell. The map indicates that the western North Pacific, the California coast, and the mid-latitude North Atlantic are among the most well-sampled regions.

Figure S2. True and sub-sampled O₂ inventory time series from CESM-LE. Each panel shows the comparison between the true O₂ inventory (black) and the sub-sampled and normalized O₂ inventory (red) for the upper 1,000m of the global ocean. The normalization follows eq 1 of the main text. The simulated O₂ fields are first interpolated onto the same grid as the observational dataset, and the climatological mean is subtracted. The sub-sampling is performed according to the actual sampling of the observational data.

Figure S3. (a) Global O₂ time series at the depth of 100m. Data points are weighted by the cosine of latitude. Black is O₂, Red and Green are O₂ saturation based on ORAS4 and SODA2.2.4 respectively. Blue is (-1) x AOU. (b) Trend matrix is formed by taking linear trend of O₂ with different starting and ending years. Color shading shows the magnitude of the trend. Hatching is applied for positive/negative definite trends with 95% CI using the method of adjusted standard error and adjusted degree of freedom following Santer et al. [2000]. (c,d) the same as (a,b) but for the northern hemispheric data points only. (e,f) the same as (a,b) but for the southern hemispheric data points only.

Figure S4. Same as S1 but for 400m.