Supplementary Material

# Supplementary Tables

|  |  |  |
| --- | --- | --- |
| **Organic carbon** | **Sea salt** | **Reference** |
| 14 | Unspecified | (Duce, 1978) |
| 6.3 (sub-micron) | Unspecified | (Gantt et al., 2012) |
| 3 | Unspecified | (Jaeglé et al., 2011) |
| 5.8 | 6297 | (Vignati et al., 2010) |
| 8 (primary and secondary sources)  5.5 (sub-micron WIOC) | Unspecified | (Spracklen et al., 2008) |
| 2.3-2.8 (WIOC) | Unspecified | (Langmann et al., 2008) |
| 13 (sub-micron) | Unspecified | (Lapina et al., 2011) |
| 75 | Unspecified | (Roelofs, 2008) |
| 2.9 (sub-micron WIOC)  19.4 (super-micron WIOC) | Unspecified | (Gantt et al., 2009) |
| 29 | 1500 | (Long et al., 2011) |
| 7.9-9.4 (sub-micron)  8.6-23 (super-micron) | Unspecified | (Meskhidze et al., 2011) |
| 17.7 | Unspecified | (Westervelt et al., 2012) |
| Unspecified | 5900 | (Gong, 2003) |

Table S1: Total estimated global emission rates (Tg yr-1) of sea salt and organic carbon in marine aerosol

\* All values refer to total organic carbon unless noted as water-insoluble organic carbon (WIOC).

Table S2: Measured concentrations (µg m-3) of organic carbon and sea salt in marine aerosol

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Location** | **Biological activity** | **Organic carbon** | **Sea salt** | **Reference** |
| Northeast Atlantic (Mace Head) | HBA | 0.619 | Unspecified | (O’Dowd et al., 2004) |
| LBA | 0.07 |
| Northeast Atlantic (Mace Head) | HBA | 0.36-3.8 | Unspecified | (Ovadnevaite et al., 2011) |
| Northeast Atlantic (Mace Head) | HBA | 0.34-0.44 (WIOC) | 0.52-0.55 | (O’Dowd et al., 2008) |
| LBA | 0.1 (WIOC) | 1.51 |
| Northeast Atlantic (Mace Head) | HBA | 1.2; 0.2 (WSOC) | Unspecified | (Yoon et al., 2007) |
| LBA | 0.1; 0.05 (WSOC) |
| Northeast Atlantic (Mace Head) | HBA | 0.11 | Unspecified | (Mansour et al., 2020) |
| Northwest Atlantic (Sargasso Sea) | Unspecified | 1.45-1.75 | Unspecified | (Keene et al., 2007) |
| Southeast Pacific | LBA | 0.01 | Unspecified | (Shank et al., 2012) |
| Northern Indian Ocean | Unspecified | 0.06-1.7 | Unspecified | ﻿(Neusüß et al., 2002) |
| Southern Indian Ocean | HBA | Maximum of >0.2 | Unspecified | (Sciare et al., 2009) |
| LBA | Minimum of <0.1 |
| Arctic | HBA | 0.11-2.93 | Unspecified | (Fu et al., 2013) |
| Arctic and North Atlantic | Unspecified | 0.1-0.4 | Unspecified | (Russell et al., 2010) |

\* All values refer to total organic carbon unless noted as water-insoluble organic carbon (WIOC) or water-soluble organic carbon (WSOC). Organic carbon values correspond to high biological activity (HBA), or low biological activity (LBA) determined by chlorophyll-*a* concentration.

Table S3: Overview of studies with observations of marine microorganisms in the atmosphere

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Location** | **Sampling Method** | **Culture-independent techniques** | **Culture-dependent techniques** | **Observed microorganisms** | **Citation** |
| North Atlantic Ocean | Cyclonic collector | Epifluorescence microscopy | None used | Bacteria, Protists, Unicellular Eukaryotes | (Mayol et al., 2014) |
| North Atlantic Ocean | PM10 air sampler | Targeted PCR, TEM, qPCR | Culturing (Liquid medium) | Eukaryotes (*Emiliania huxleyi*), Viruses (*Eh*V) | (Sharoni et al., 2015) |
| Northeast Atlantic Ocean (Mace Head) | Passive deposition sampler | 16S and 18S rRNA gene sequencing | None used | Bacteria, Archaea, Protists, Fungi | (Cáliz et al., 2018) |
| Atlantic Ocean | PM10 air sampler | 16S rRNA gene sequencing, qPCR | None used | Bacteria, Archaea | (Fröhlich-Nowoisky et al., 2014) |
| Carribean Sea, Gulf of Mexico, and Midwestern Atlantic Ocean | Vacuum pump | Epifluorescence microscopy, 16S rRNA gene sequencing, and qPCR | None used | Bacteria, Fungi | (DeLeon-Rodriguez et al., 2013) |
| Atlantic and Arctic Ocean | Impinger | 16S rRNA gene sequencing | Culturing (Agar plate and Mesocosms) | Bacteria, Phytoplankton | (Fahlgren et al., 2015) |
| Northern and Western Pacific Ocean, Actic Ocean, and Norwegian Sea | Cascade impactor | 16S rRNA gene sequencing | None used | Bacteria | (Xia et al., 2015) |
| Pacific Ocean | Spore trap | 16S and 18S rRNA gene sequencing | None used | Phytoplankton | (Sherwood et al., 2020) |
| Pacific Ocean | Cascade impactor | 16S and 18S rRNA gene sequencing | Culturing (Agar plate) | Fungi, Bacteria | (Urbano et al., 2011) |
| Atlantic, Pacific, and Indian Ocean | Cyclonic collector | Epifluorescence microscopy, 16S rRNA gene sequencing | None used | Bacteria, Archaea, Fungal spores, Protists | (Mayol et al., 2017) |
| East and South China Sea, South Pacific, East Indian, South Atlantic, and Southern Ocean | High-volume filter sampler | 5S rRNA gene sequencing | None used | Fungi | (Fröhlich-Nowoisky et al., 2012) |
| South Baltic Sea | Cascade impactor | Light and epifluorescence microscopy | Culturing (Liquid medium) | Phytoplankton | (Lewandowska et al., 2017) |
| Baltic Sea | Sartorius air filtration unit | None used | Culturing (Agar plate) | Bacteria | (Marks et al., 2001) |
| North Sea and Baltic Sea | Impinger | 16S rRNA gene sequencing | None used | Bacteria | (Seifried et al., 2015) |
| East Sea | Impinger and Filtration | Epifluorescence microscopy, 16S rRNA gene sequencing, and qPCR | Culturing (Agar plate) | Bacteria, Archaea | (Cho and Hwang, 2011) |
| Southeast Mediterranean Sea | High-volume filter sampler | Flow cytometry, 16S rRNA gene sequencing, and Bacterial enzyme activity | Culturing (Microcosms) | Bacteria | (Rahav et al., 2016) |
| Southern Ocean | Filtration | 16S rRNA gene sequencing | None used | Bacteria, Archaea | (Uetake et al., 2020) |
| Arctic Ocean | Impactor and Electrostatic precipitator | TEM | None used | Bacteria, Viruses | (Leck and Bigg, 2005) |
| Arctic Ocean | Impactor and Electrostatic precipitator | TEM | None used | Bacteria, Diatoms | (Bigg and Leck, 2001) |

\*TEM refers to transmission electron microscopy

**Figures 1 and 2 calculations: deposition velocity, distance travelled, and residence time**

The deposition velocity for an aerosol particle was calculated using Stokes’ Law where is the particle density , is the diameter of the particle, is the acceleration of gravity , is the coefficient of air viscosity (, and is the mean free path of gas molecules The Cunningham Correction Factor was used for particles with a diameter of < 1 m to account for slippage past gas molecules. Settling velocities were calculated at the average tropospheric temperature (15°C). Starting altitudes (0 m, 250 m, 500 m, 750 m, and 1000 m) assumed the particle would be lofted into the atmosphere at this height and the distance travelled and residence time in the atmosphere was calculated using an average windspeed of 10 m s-1. An average density of 1.1 was used for biological particles (Mayol et al., 2014), and a relative humidity of 70% was used to determine density and viscosity in the troposphere (Williams, 1982).

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