

GLOBAL DISTRIBUTION OF COCCOLITHOPHORE BLOOMS

By Christopher W. Brown

BLOOMS OF THE COCCOLITHOPHORE *Emiliania huxleyi* regionally act as an important source of dimethyl sulfide (DMS) and calcium carbonate and alter the optical properties of the surface mixed layer (Balch *et al.*, 1991; Holligan and Balch, 1991). These blooms, often covering vast areas, can be identified in visible satellite imagery because of the large amount of light backscattered from the water column. Their presence gives the ocean a milky white to turquoise appearance. The ability to detect *E. huxleyi* blooms in satellite imagery, in addition to furnishing biogeographical knowledge of the species at time and space scales unattainable with shipboard sampling, provides a method to assess their biogeochemical importance on basin to global scales.

Global composites of Coastal Zone Color Scanner (CZCS) imagery (Feldman *et al.*, 1989) were used to map the distribution pattern of *E. huxleyi* blooms and to estimate the magnitude and periodicity of their CaCO₃ and DMS production in the world's oceans (Brown and Yoder, 1994). Pixels of 5-day composite imagery from the entire CZCS mission (November 1978 to June 1986) were classified into either bloom or nonbloom classes based on their mean normalized water-leaving radiances using a supervised, multispectral scheme. This empirically based classification technique is common in terrestrial remote sensing but has only recently been applied by oceanographers. A classification algorithm was developed which compared the spectral signature of known *E. huxleyi* blooms (e.g., Holligan *et al.*, 1983) to spectral signatures of nonbloom conditions. Spectral signatures of *E. huxleyi* blooms, "clear" blue water, sediment-laden water, "whiting" (suspended lime muds), and atmospheric haze were extracted from CZCS imagery. Decision boundary values for each of five spectral feature characters were assigned

that would allow the blooms to be spectrally distinguished from the other conditions. An independent data set was also used to establish that the algorithm was effective in distinguishing coccolithophore blooms from the other water conditions, with the exception of whittings, at the spatial resolution of the global imagery. The classified images generated from the scheme were then combined into monthly, annual, and mission climatologies of bloom and nonbloom locations.

Spectral signatures similar to that of *E. huxleyi* blooms were found to be most extensive at subpolar latitudes, particularly in surface waters of the North Atlantic, the North Pacific, and the Argentine shelf and slope (Figure 1). Classified blooms covered an average of 1.4×10^6 km² annually, with the subpolar latitudes accounting for 71% of this area. The classified blooms at these higher latitudes were inferred to represent the presence of *E. huxleyi* blooms because the classification scheme proved efficient in these regions and their locations are supported by previous biogeographic investigations. Numerous classified blooms, often quite extensive, were also detected in low-latitude marginal seas, though the conditions responsible for this signal are equivocal. Seasonally, the classified blooms in subpolar oceanic regions achieved their greatest spatial extent in summer to early autumn, while those in lower latitudes peaked in midwinter to early spring.

Two important caveats of this approach should be noted. First, the results displayed in Figure 1 reflect the distribution pattern of coccolithophore blooms occurring in the surface layer and are biased toward the declining stage (stationary phase) of the bloom. Detection of blooms is sensitive to light backscattered from approximately one attenuation depth and is primarily a function of detached coccolith concentrations. Blooms composed primarily of cells or occurring at depths deeper than that sensed by the CZCS would be missed. Second, the distribution pattern of blooms and their spatial extent are biased by both image coverage and regional atmospheric conditions.

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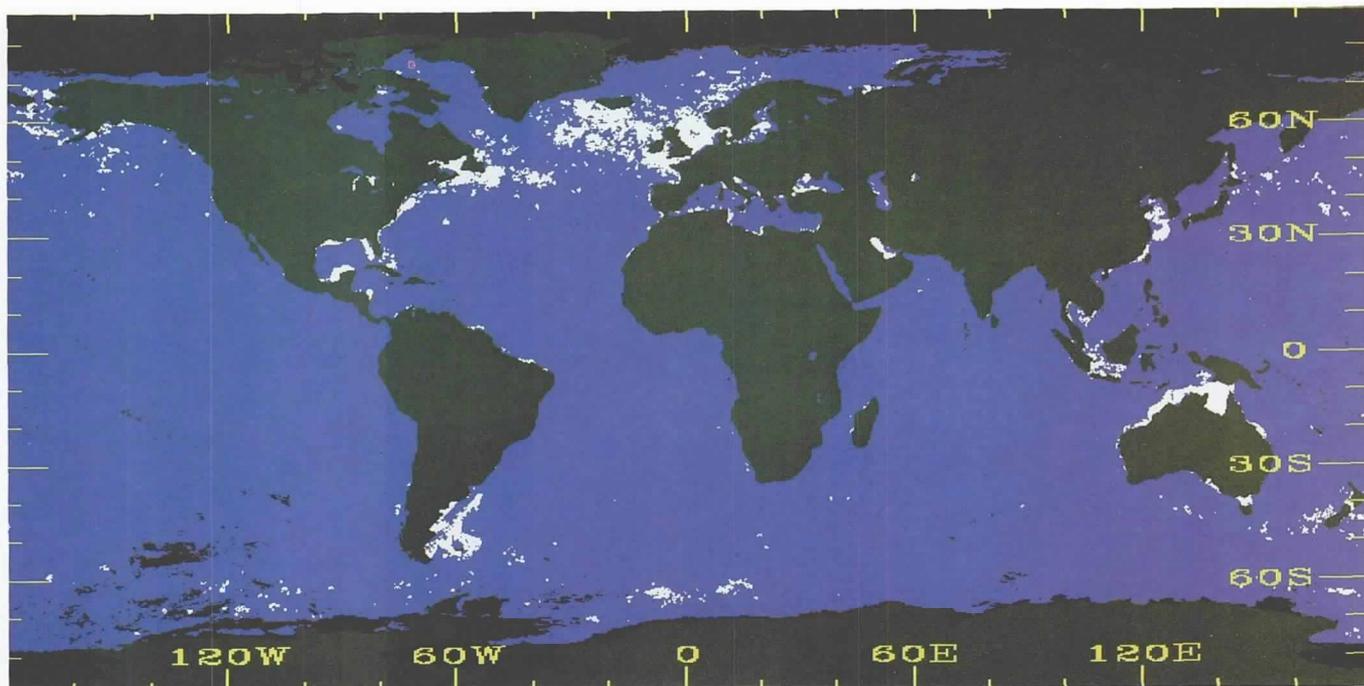


Fig. 1: Mission climatology of classified coccolithophore blooms in the world's oceans. The maximum spatial extent of blooms detected during this period are displayed. Coccolithophore bloom class, white; nonbloom class, blue; land, green; lack of data, black (From Brown and Yoder, 1994).

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The amount of calcite-carbon and DMS-sulfur produced by the classified *E. huxleyi* blooms was estimated using the mean annual areal extent of the blooms and representative values of mixed layer depth, average cell concentrations found in blooms, DMSP concentration per cell, and mass of calcite per coccolith. The blooms detected at subpolar latitudes (40–60°) are estimated to produce an average of $0.4\text{--}1.3 \times 10^6$ metric ton CaCO_3 carbon and 1×10^4 tm DMS sulfur annually. These standing stock estimates suggest that satellite-detected blooms play only a minor role in the annual production of calcite and DMS on a global scale.

Although no satellite ocean color sensor has operated since the demise of the CZCS in June 1986, future missions, such as the Sea-viewing Wide-Field-of-View Sensor (SeaWiFS), will allow *E. huxleyi* blooms to be monitored once again. These dedicated ocean color missions, in conjunction with techniques to estimate coccolith and cell concentrations in coccolithophore blooms from satellite imagery (Ackleson *et al.*, 1994), will improve our ability to assess the impact of coccolithophore blooms on the carbon and sulfur cycles in the future.

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