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Bio-optical variability associated with phytoplankton dynamics in the North Atlantic Ocean during spring and summer of 1991

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Abstract. Bio-optical data recorded from April 30 to July 19, 1991, using a mooring located in the open ocean (59°35.6'N, 20°57.9'W) are described and interpreted. Five multi-variable moored systems (MVMS) were deployed in the upper 90 m to obtain concurrent, co-located measurements of horizontal currents, water temperature, photosynthetically available radiation (PAR), transmission of light at 660 nm (c_{660}), and stimulated chlorophyll fluorescence. In addition, meteorological and subsurface temperature data (12 depths from 80 to 310 m) were collected. When the mooring was deployed, surface waters were weakly stratified and there was little evidence of a phytoplankton bloom. Soon after the deployment, a marked increase in phytoplankton concentration occurred simultaneously with an increase of near-surface water temperature. The most striking observation was a period (year days 128-140) of strong mixed layer depth variability (daily amplitude of about 40 m) during which phytoplankton standing stock reached its maximum. During this period, phytoplankton biomass was mixed down to deeper waters at nighttime. As a result, the variability of the bio-optical parameters was extremely high, and deepwater phytoplankton concentration was much greater than would have been expected from the productivity estimates. Later, phytoplankton concentrations declined sharply in response to extremely stormy weather around year day 140. Once the storm passed (after day 143), surface waters stratified and the phytoplankton stock increased again, but the depth integrated biomass concentration did not reach as high values as before the storm. During this strong thermal stability period, fluorescence and c_{660} signals in near-surface waters were much higher than at depth, and displayed a diel cycle which was well correlated with PAR.

Introduction

Phytoplankton blooms in the North Atlantic have been investigated in the past by various means, including coarse resolution time series obtained from ocean weather station ships and continuous plankton recorders deployed from ships of opportunity [e.g., *Williams*, 1975; *Colebrook*, 1979]. Later, much attention was directed toward Coastal Zone Color Scanner (CZCS) data for the North Atlantic. These data revealed that the open ocean can sustain intense blooms over vast areas and extended time periods [*Esaias et al.*, 1986]. Recently, a few international research programs have been conducted to cover relatively large spans of time in the North Atlantic area [*Ducklow and Harris*, 1993]. Included among these efforts was the Marine Light - Mixed Layer (MLML) program which conducted field experiments in 1989 and 1991.

One of the important MLML strategies was to use moorings which allow sampling of physical and bio-optical variables at a fixed position in space, over time periods of several months, and with resolution of the order of minutes [*Dickey*, 1991; *Dickey et al.*, 1991, 1993, 1994]. Bio-optical variables can reveal abundances of phytoplankton, which play a key role for optical variability in the open ocean [*Jerlov*, 1976; *Kirk*, 1983; *Morel and Prieur*, 1977; *Smith and Baker*, 1978]. For example, beam attenuation coefficient measurements at 660 nm are correlated with particle concentration [e.g., *Bartz et al.*, 1978; *Bishop*, 1986; *Bishop et al.*, 1986, 1992; *Spinrad et al.*, 1989; *Gardner et al.*, 1993], while stimulated fluorescence is correlated with chlorophyll concentration [e.g., *Smith and Baker*, 1986; *Bartz et al.*, 1988]. Thus, a mooring using such instrumentation is ideal for the examination of the physical/biological feedbacks within the mixed layer and the fate of phytoplankton populations.

An overview of the MLML mooring data collected in 1989 has been given in another paper [*Dickey et al.*, 1994] and more detailed aspects of the bio-optical variability have been discussed by Stramska and Dickey [1992b, 1993, 1994]. The present paper focuses on the fundamental time-depth variability of bio-optical parameters as recorded by the mooring instruments during the period of April 30 to July 19, 1991 (year days 120-200). The primary objectives of the paper are: (1) to quantify the temporal patterns of phytoplankton variability in the northeast Atlantic; (2) to identify and clarify the roles of various mechanisms that control the phytoplankton biomass in the water column, and particularly, to examine the progression of a spring bloom with the seasonal stratification of surface waters; (3) to form the basis of a framework for the interpretation of the biological and chemical processes investigated in shipboard surveys [e.g. *Langdon* et al., this

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