Changes in dominant mixing length scales drive phytoplankton bloom initiation in the subpolar North Atlantic

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The timing of the subpolar phytoplankton bloom has important consequences for marine ecosystems and carbon export to the deep ocean. The conventional explanation of subpolar phytoplankton bloom timing maintains that as the upper ocean stratifies in the spring, phytoplankton mix to shallower depths, experience higher light levels, and begin to bloom. However, recent studies have challenged this theory and proposed new explanations for the initiation of the bloom. One such explanation posits that decreases in upper mixed-layer turbulence, rather than seasonal stratification, reduces the depth to which phytoplankton are mixed, thereby increasing light exposure and promoting a bloom. The decrease in turbulence has been attributed to the onset of ocean surface net heating and lowered wind stress.

Recognizing that seasonal stratification, net ocean warming, and decreasing wind strength have all been invoked to explain how phytoplankton can increase their light exposure within a one-dimensional, light-limited system, we examine these mechanisms individually for the subpolar North Atlantic. We then reframe the discussion of light exposure in terms of the dominant mixing length scale, and allow that scale to be set at times by the local buoyancy forcing, and at times by the local winds. We find that decreases in this length scale better predict bloom initiation than do changes in seasonal stratification or individual forcings. Our model can also provide an alternative explanation for conditions observed during the bloom initiation in other studies that have invoked top-down mechanisms and three-dimensional processes to explain the timing of subpolar phytoplankton blooms.