New technological developments for ocean LIDAR biomonitoring

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ABSTRACT

A pump-and-probe (P&P) airborne LIDAR has been recently developed at NASA Goddard Space Flight Center. It provides remote measurement of phytoplankton photosynthetic variables along with pigment and organic matter fluorescence, down-welling and upwelling hyperspectral measurements and sea surface temperature. The utilization of an airborne platform provides for rapid remote characterization of phytoplankton photosynthetic activity, biomass and diversity over large aquatic areas. The P&P LIDAR technique is one of the first practical implementations of 'superactive' remote sensing. This presentation summarizes results of six airborne measurement campaigns conducted in 1999-2002 in the Chesapeake Bay, Delaware Bay, Middle Atlantic Bight, and Gulf of Mexico. The P&P technology has been complemented by a Laser Phytoplankton Analyzer (LPA), a shipboard laser fluorometer dedicated to technological advancement in pigment analysis that will be implemented in future LIDAR systems. It combines high-resolution spectral measurements of phytoplankton pigment fluorescence excited at several selected wavelengths with active assessment of the physiological status of the phytoplankton photosynthetic apparatus. Emission/excitation measurements provide a potential for assessing concentrations of photosynthetic accessory pigments (Chlorophyll *a, b, c,* photosynthetic carotenoids and phycobilins) and identifying major phytoplankton functional groups. The LPA was extensively tested in laboratory experiments with phytoplankton cultures and their mixtures. In November 2002, the LPA was utilized for pigment fluorescence analysis of natural phytoplankton over a range if environmental conditions on a research cruise in the Middle Atlantic Bight and Delaware Bay.

Keywords: LIDAR, remote sensing, airborne, biomonitoring, ocean, pump-and-probe, fluorescence, photosynthesis, biomass, pigment analysis, phytoplankton

1. INTRODUCTION

Coastal and estuarine waters are highly productive and complex ecosystems, but efforts to examine them on large spatial and temporal scales are largely limited to remotely-sensed estimates of chlorophyll *a* (Chl) biomass. An advanced pump-and-probe (P&P) airborne laser technology has been recently developed at NASA Goddard Space Flight Center. The P&P system provides remote measurement of important phytoplankton photosynthetic variables, such as the functional absorption cross-section of photosystem II (PSII), PSII photochemical efficiency, PSII turnover time, the rate parameters of singlet-singlet and singlet-triplet annihilations, and carotenoid triplet lifetime along with pigment and organic matter fluorescence, down-welling and upwelling hyperspectral measurements and IR surface temperature. The utilization of an airborne platform provides the potential for rapid remote characterization of phytoplankton photosynthetic activity, biomass and diversity over large aquatic areas at synoptic space/time scales.

The P&P LIDAR technique is one of the first practical implementations of 'superactive' remote sensing. The distinguishing feature of this new class of technique is the ability to remotely cause desirable changes in the subject's functionality to retrieve additional information unattainable with any other passive or active techniques. The P&P technology may be complimented by recent developments in technology to assess phytoplankton taxonomic variability from airborne LIDAR measurements. This research is primarily focused on multicolor laser excitation of Chl and phycobilin fluorescence bands to remotely implement this fluorescence excitation technique. A laboratory prototype of the Laser Phytoplankton Analyzer (LPA) shipboard system has been successfully tested with representative sets of phytoplankton cultures and their mixtures. Both P&P and LPA systems provide new unique capabilities for advanced laser biomonitoring in the coastal areas. Below we present examples of the initial utilization of the P&P technique for

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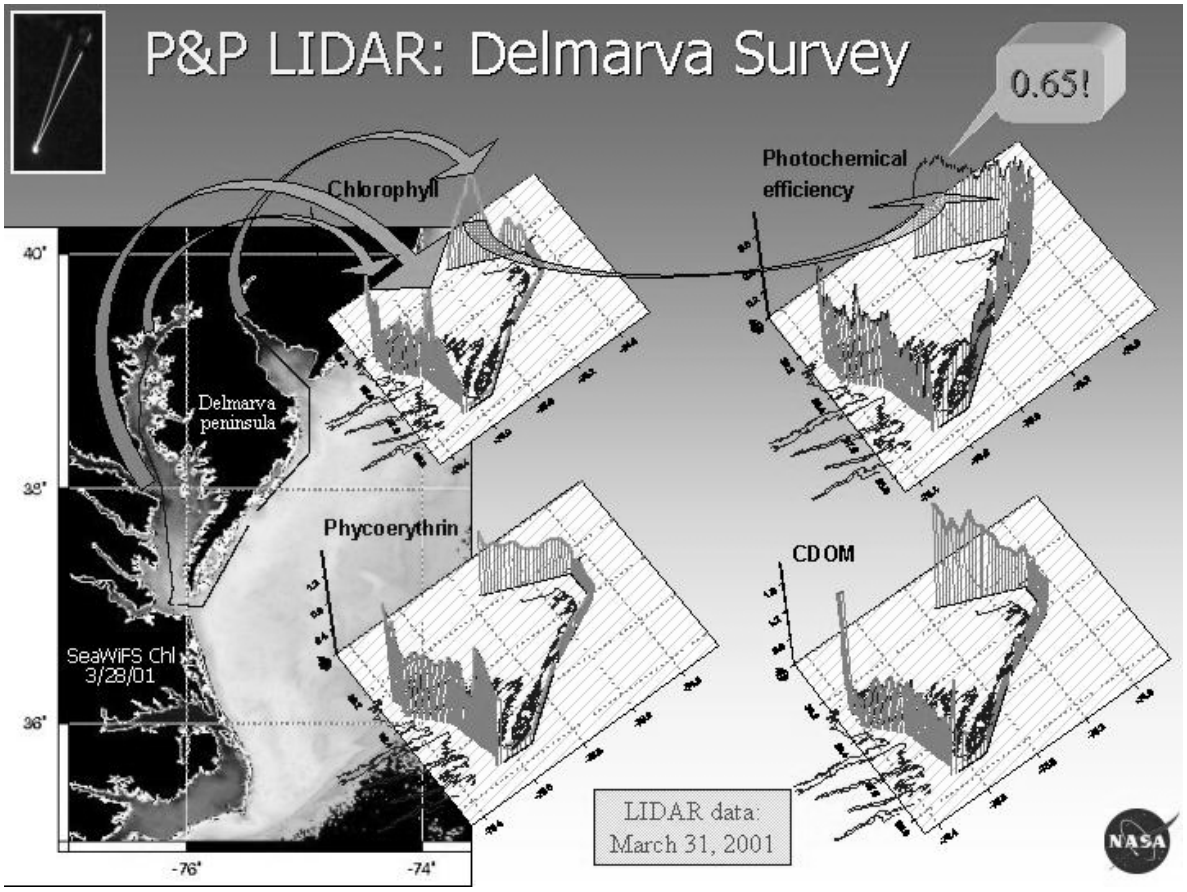
advanced LIDAR biomonitoring in the US coastal and near-shore areas. The potential of the LPA technology for improved taxonomic, pigment and physiological analysis of phytoplankton is discussed.

2. OCEANIC AND COASTAL BIOMONITORING WITH AN AIRBORNE P&P LIDAR

In October 2000, we initiated airborne LIDAR surveys to study dynamics and/or spatial variability of phytoplankton photochemical characteristics, pigment and CDOM fluorescence in coastal areas of the Middle Atlantic Bight, in the Chesapeake Bay, Delaware Bay and Pamlico Sounds (NC). An example of such measurements around the Delmarva Peninsula is presented in Fig. 1 for a survey conducted on March 31, 2001. Only 3 hours were required to acquire the informative high-resolution data set for detailed characterization of the area. Generally, Atlantic coastal areas of Delmarva Peninsula were found to be less productive (see ~10 times lower Chl and phycoerythrin content) than respective areas in the middle/upper Chesapeake and Delaware bays. Distributions of Chl were in general agreement with SeaWiFS Chl data (left insert), but provided more detailed information about spatial variability in relation to important taxonomic and environmental characteristics such as phycoerythrin, CDOM and sea surface temperature. Photochemical efficiency in upper Delaware Bay was high (~0.65) and comparable to levels found under ideal conditions in the laboratory indicating that the population was in robust physiological condition at the time. This is consistent with early bloom development in Delaware Bay occurring in response to increased light-levels under nutrient-replete conditions as stratification develops.

Figure 1: An example of the P&P LIDAR survey around Delmarva Peninsula.



Monitoring the effects of light- and nutrient status on a wide array of taxa would allow an informed interpretation especially when data on natural populations is collected synchronously with that on proxies for the physical environment (temperature, attenuation as an indicator of resuspension and sediment transport, CDOM as a tracer of freshwater inputs, etc.). We have already conducted 4 such P&P LIDAR surveys around the Delmarva Peninsula in October 2000, March 2001 (2 surveys) and March 2002. These acquired data sets provide a potential for studying dynamics of spatial variability in bio-environmental characteristics over a range of temporal scales, including seasonal.