Optical Complexity of Coastal and Offshore Oceanic Waters: Implications for Shipboard, Airborne and Satellite Retrievals

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Abstract

Measurements of key bio-environmental An extensive series of hyperspectral measurements of laser-stimulated emission (**LSE**) with multiple excitation wavelengths was conducted in the Middle Atlantic and Southern California Bights, California Current, Chesapeake, Delaware and Monterey Bay in 2005-2008. The data revealed significant optical complexity and variability of the LSE signatures in both coastal and offshore waters. The spectral deconvolution (**SDC**) analysis, which involves 15 spectral components, was developed to assess the key fluorescence constituents, including chlorophyll-a (**Chl-a**), phycobiliproteins (**PBPs**) and chromophoric dissolved organic matter (**CDOM**). It provides for discriminating 3 spectral types of phycoerythrin and assaying spectral variability in Chl-a fluorescence associated with photo-physiological and structural changes in phytoplankton populations. Potential for in vivo discrimination between cryptophytes and cyanobacteria, and assessment of their abundance in the mixed algal populations was demonstrated. The blue spectral shift in Chl-a fluorescence may allow detection and assessment of dinoflagellates in the phytoplankton communities. Three spectral bands peaking at 625, 644 and 662 nm detected in the field may be interpreted as fluorescence from partially dysfunctional photosynthetic apparatus of phytoplankton. The measurements suggest necessity (i) of hyperspectral LSE measurements and SDC analysis in various settings, including in situ, shipboard and airborne instruments, and (ii) of spectral correction of variable fluorescence measurements used for phytoplankton photo-physiological assessments. The use of the advanced laser fluorescence (**ALF**) measurements onboard airplanes and fast-moving vessels for improved calibration/validation of the satellite retrievals in coastal waters is discussed. The field observations that show potential for assessment of the PBP pigments from ocean color measurements are presented.
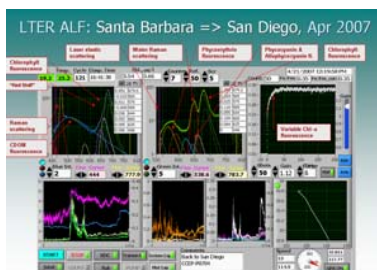
Spectral Fluorescence Analysis
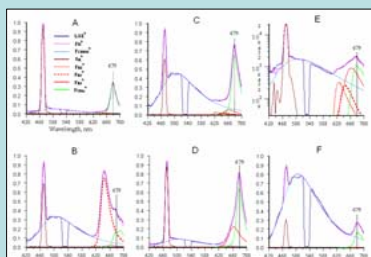
LSE spectral variability in diverse water types (**405 nm** excitation).
A: surface, Southern California Bight. **B:** lower Delaware Bay. **C:** lower Delaware Bay. **D:** Southern California Bight. **E:** sample from 100 m depth, same location as (A). **F:** Delaware River
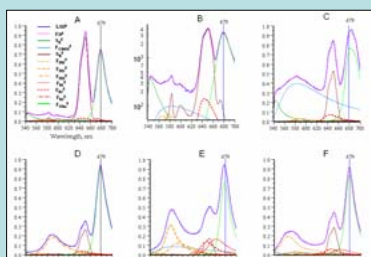

LSE spectral variability in diverse water types (**532 nm** excitation).
A: Southern California Bight. **B:** Same as (A) but logarithmic scale. **C:** Delaware River. **D:** Coastal zone of the Southern California Bight near Point Conception. **E:** Lower Chesapeake Bay. **F:** Middle Atlantic Bight, vicinity of the Delaware Bay mouth

Measurements of Spatial Variability in Aquatic Fluorescent Constituents

Spectral Fluorescence Assessments of Phytoplankton Functional Groups
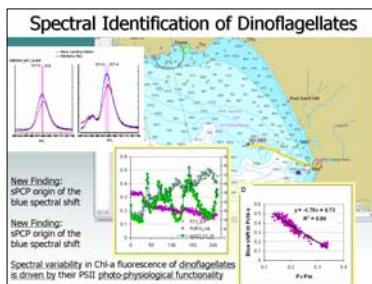

The dinoflagellate-specific "blue shift" in the spectral peak of Chl-a fluorescence may provide potential for their detection and identification in the mixed phytoplankton populations.
D: High anti-correlation was found between the "blue shift" and the physiological status of phytoplankton indexed via variable fluorescence, Fv/Fm.
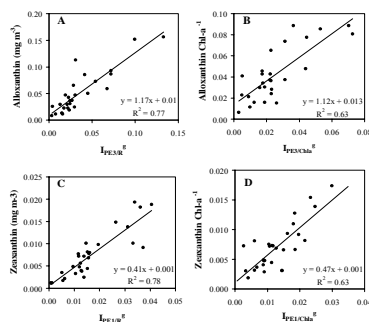

Assessment of the PBP-containing groups : Correlations of the group-specific PE spectral fluorescence indexes with HPLC measurements of alloxanthin and zeaxanthin, the carotenoid biomarkers for the cryptophytes and cianobacteria, respectively (Southern California Bight, Apr. 2007).

## Laser Fluorescence Validation of Satellite Chl-a retrievals
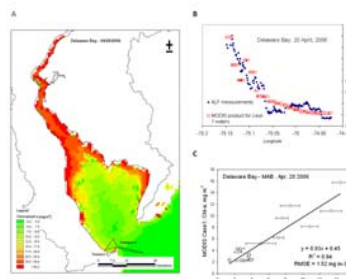
Validation of satellite remote sensing using underway flow-through measurements with the Advanced Laser Fluorometer (ALF) onboard a small vessel. **A:** The GPS boat track (black line) and Chl-a distribution (MODIS algorithm for case 1 waters). **B, C:** Chl-a transect distributions measured with the ALF instrument vs. retrieved from the satellite ocean color.

## Spectral Fluorescence Retrievals of Seawater Constituents
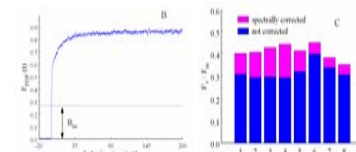
Spectral correction of photo-physiological assessments

(**B**): Fluorescence induction, $F_{PDP}(t)$, measured by the ALF instrument; B_{NC} is a non-Chl-a fluorescence background;
(**C**): Subtraction of B_{NC} from $F_{PDP}(t)$ yields in up to 35% larger magnitudes of variable fluorescence, F_v/F_m, as compared to the non-corrected values.
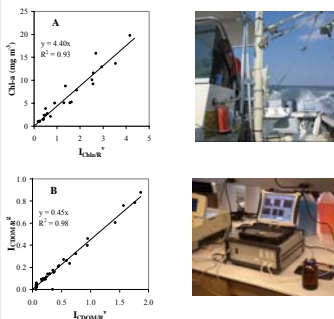

Chlorophyll-a and CDOM

Spectral deconvolution of seawater emission signatures allows for the **accurate assessments of phytoplankton pigments and chromophoric dissolved organic matter (CDOM)**

Potential for Retrieving Phycobiliproteins from Ocean Color
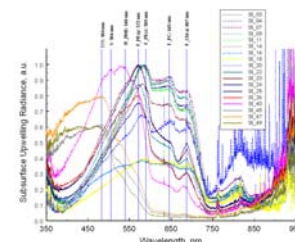
Comparative analysis of in situ measurements of **spectral reflectance (passive**; Dr. A. Gitelson) **and laser-stimulated emission (active**, ALF data) in the Delaware Bay and adjacent area of the Middle Atlantic Bight has shown the potential for **retrieving phycoerythrin** and, possibly, **phycocyanin from the hyperspectral measurements of the ocean color**.

NASA Airborne Oceanographic LIDAR: Hyperspectral Upgrade
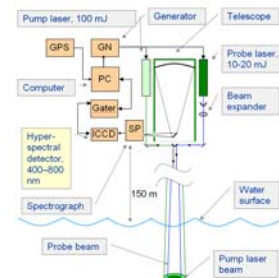
Conclusions

Oceanic waters, including the case 1 offshore environments, are optically complex and require hyperspectral measurements and spectral deconvolution (SDC) for the accurate active assessments of the fluorescent aquatic constituents (Chl-a and PBP pigments, CDOM, F_v/F_m)

In situ, shipboard, and airborne fluorosensors should provide:
– Selective (at least, dual-wavelength) excitation
– Broadband (at least, 400-750 nm) hyperspectral detection
– Spectral deconvolution for assessment of the seawater constituents
– Spectrally corrected photo-physiological assessments

The underway laser fluorescence measurements onboard small vessels can be used for cost-efficient mesoscale validation of the satellite retrievals in coastal waters

Active fluorescence measurements provide for quantitative characterization of phycobiliprotein-containing cryptophytes and "oceanic" vs. "coastal" cyanobacteria in the mixed phytoplankton populations

Spectral identification of dinoflagellates is feasible, but needs refining with regard to their photophysiological variability