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Fifty years of inherent optical properties

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ABSTRACT

This paper describes my career in Ocean Optics over nearly half a century. It was centered around the Inherent Optical Properties (IOP, the scattering and absorption properties of sea water and its dissolved and suspended materials). The paper describes the development of instrumentation for the measurement of the IOP, the applicable theories, and the inversions to obtain biogeochemical parameters. This is not intended to be a thorough review, but rather describes a personal journey.

Introduction

The ocean is a dilute soup of suspended particles and dissolved materials. The particles consist of living phytoplankton and zooplankton as well as inorganic materials from resuspension, river runoff, airborne particles, etc. These particles and dissolved materials affect the transmission and absorption of light. The intensity, directionality, and spectrum of the underwater light (the light field) in turn affects the yield of organic materials and the oxidation of organic materials. The optical properties of the particulate and dissolved materials are known as the Inherent Optical Properties (IOP) (Preisendorfer, 1965, 1976). They are called inherent because they are not directly affected by the light field. Conversely however, the IOP directly affect the light field. We thus see that the nature and concentration of particulate and dissolved materials determine the IOP, and the IOP determine the light field in the ocean (together with the incoming light field at the sea surface). In turn, all biological, geological, chemical, and physical processes have some effect on the shape, size, or index of refraction of the particles, the dissolved material, or the water itself, and hence on the IOP of sea water with all its constituents.

All biological, chemical, geological, and physical processes in the ocean result in some change of the IOP of the dissolved and suspended materials or the optical properties of the sea water itself.

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There are thus a number of interesting problems associated with the IOP:

- How do the properties of particulate matter (size, shape, index of refraction distribution) determine the IOP of the particles?
- How do the properties of the dissolved materials determine their IOP?
- How do the IOP affect the intensity, directionality, and spectrum of the underwater light (the problem of radiative transfer)?
- If we know some of the IOP (absorption and/or scattering characteristics), what parameters of the particulate and dissolved materials can we determine?
- How can the IOP be used to determine the spatial and temporal distribution of the particulate and dissolved materials, and study the processes that determine those distributions?
- How can the light field above, such as determined by satellite sensors, or below the ocean surface be used to determine the IOP, and, in turn, the characteristics and distribution of particulate and dissolved materials?
- How do physical processes (temperature and salinity changes, turbulence) affect the absorption and scattering characteristics of the sea water?
- How can we design and build instrumentation to measure the IOP in the ocean, as well as their spatial and temporal distributions?

These problems, all associated with the IOP one way or another, kept me occupied during a 48-year long career in Ocean Optics.

Personal background

I was born at the end of World War II in the German occupied Netherlands. My father was a marine biologist, hiding from the Germans, as he had been ordered to work for them and he refused to do so. The allies had penetrated to the Rhine river in the summer of 1944, but did not manage to cross until nearly a year later. That time was known as the hunger winter as the German occupiers kept all the food for themselves. It was left to my mother to scour the countryside for food for the family and the Jewish people hiding in the basement. She had an old bicycle with garden hose for tires and regularly had to run German roadblocks.

After the war we moved to the Dutch East Indies (now Indonesia), where my father collected and classified macro algae. We went through the Indonesian revolution there and I started grade school. After the revolution we moved back to the Netherlands. Several years later my father founded the Caribbean Marine Biological Institution in Curaçao. I went to high school there. In Curaçao I learned to sail and dive, activities I have enjoyed for the rest of my life.

In 1960 we moved to Norfolk, VA where my father had obtained a professorship at Old Dominion University, and where he founded the Oceanography department. I did the last year of high school in Norfolk and attended Old Dominion University, where I earned a B.S. degree in Physics.

In 1964 I obtained a Woodrow Wilson fellowship to do graduate work in Physics at M.I.T. While I was there my father had been collecting algae under the ice in Antarctica. He noticed that algal growth was surprisingly active under the ice even early in the spring. He asked if I knew anything about sea ice optical properties. There was very little literature on the optical properties of sea ice at the time, so I decided to see if one could measure it in the laboratory. I made some cuvettes and made ice of different salinities and then ran them through a spectrophotometer. I had loaned the spec. from George Beardsley, who I had met at the sailing club, and who was finishing his Ph.D. work at M.I.T. George had been offered an Assistant Professorship in Oceanography at Oregon State University (OSU). He asked me if I wanted to be his graduate student there. This seemed like a great idea as we were interested in the same ocean optics problems. Besides, I had never been west of the Appalachians. I finished a Master's Degree at M.I.T. and moved to Oregon.

Ocean optics in the 1960's

In the 1960's the Oceanography department at OSU was a growing and vibrant place. The founder was Wayne Burt, who had done Ocean Optics work and had appointed George Beardsley to start