1.11 Future Problems of Hydrologic Optics

The present introductory chapter to hydrologic optics is brought to a close with a .small, carefully selected list
of important problems which are as yet only partially resolved* The list is deliberately kept small so as not to overwhelm prospective students of the subject with a mass of more or less obvious types of applicational problems they-soon would encounter in their own fashion as their studies proceed. Rather, we have selected for presentation and discussion here three archetype problems which, if eventually satisfactorily resolved, would elevate the discipline of hydrologic optics to the level of a mature science which could predict and describe, in the fullest sense of these terms, all aspects of
the transfer of radiant energy in the seas, lakes and other natural hydrosols of the world,

Problem One: To Establish Theoretically the Physical Basis of the Inherent Optical Properties of Natural Hydrosols

The two main inherent optical properties a, a, of the hydrosols, and of optical media in general defined in Sec. 1.6, together with the equation of transfer ((lo) or (12) of Sec. 1.3) form the core of modern radiative transfer theory. This theory is by definition (i.e*, by actual considered choice) predominantly phenomenological in outlook, and accordingly the optical properties a, a are left unspecified in the general theory. The theory thus contains no formalism which predicts the values of a and a in a given medium in terms of *the inherent physical structure of that medium. It is impor*tant to understand the significance of this observation. It does not maintain that the theory of radiative transfer is incapable of providing procedures to measure a and a in natural optical media. The operational procedures in Sec. 1.6 and in Chapter 13 below supply abundant methods for arriving at a and a in given media. Rather, what is intended is the observation that the *connections between a and a and the electromagnetic structure, and more* basicall*y, the molecular structure of these media is beyond the ken of the principles of the theory.* The purpose of Problem One is to establish theoretical connections between a and a and the physical properties of an hydrosol--i.e., the properties of a given solution or suspension (or both) of substances in H_2O. One such connection is possible on the electromagnetic level wherein a and a could be related *theoretically to* the permitivity permittivity, permeability, and conductivity functions of the hydrosol. Such connections have received initial attention in Chapters XIV and XVI of Ref. (251], and the results there suggest further directions in which to pursue this problem. Observe that the approach in [251] is not the approach of the Mie theory of scattering since the latter applies only to single scatterers. The suggested approach attempts to obtain a basis for a as actually measured in situ. The motivation for Problem One is quite clear: if this problem is solved, it may someday be possible to predict, by calculation, the *a and a of an hydro*sol, given its physical analysis; and conversely, from a spectral radiometric analysis of a and a, to determine *the physic*al components of the hydrosol. It may then also be possible to resolve once and for all the quantitative and conceptual problems of the nature of forward scattered light for very small and very large angles of scatter (see Sec. 1.6, in particular Fig: 1.72; Sec. 18 of Ref. (251], and

[78]) and also to provide a rational basis for such interesting findings as displayed in Table 4 and Fig. 1.73 of Sec. 1.6, of the uniformity of shape of a. Furthermore, by solving Problem One, we may also resolve such questions as the existence of spectral windows in the sea which even though seemingly settled on an empirical level (cf., Sec. 1.6) will continually nag at the analytically inclined individual who would prefer such an important question to be resolved in a way which rests on necessary inferences drawn from established physical principles;

principles which **are, incidentally, on a more fundamental level than those on** which radiative transfer theory is made to rest. Still further, the problem of the structure of o in the polarized context (using the matrix p) may be solved (see Sec. 13,,11),ˉ Last, but not least, *the* resolution of the present problem will securely anchor the discipline of hydrologic optics, and radiative transfer in general, to the mathematical and physical bedrock of the mainland of modern physics.

Problem Two: To Establish Complete Empirical Classifications of Natural Hydrosols

The discussion of this problem was essentially presented in-Sec. 1.7, and so need not be repeated here. It should per* haps be emphasized that this problem is unquestionably the single most important problem facing experimenters in the field of hydrologic optics. A moment's reflection will show the experimenter (who is for example bent on the problem of the connections between the ideal photosynthesis in a region and the measurement of radiant energy in that region) that this problem is essentially one of classification of an optical medium in either of the three main modes (Modes I, II, III) described in Sec: 1.7, Or again, a scientist concerned with the problem of underwater optical communication or visibility will benefit from complete empirical classifications of the media of interest. Even theoreticians, on descending from their ivory towers after making some inroads into Problem One above, will require corroboration of the kind that only a truly exhaustive solution of the present problem can supply.

Perhaps we can put the nature of the present problem into perspective by enjoining the prospective experimenter on what not to do if his work is to contribute to the solution of Problem Two and is to be of lasting worth and importance to the discipline of hydrologic optics:

(i) Do not omit to mention the spectral range and accuracy of your determinations of the optical properties.

(ii) Avoid broad-band measurements whenever narrow band measurements are possible, even if considerably more effort is entailed for the latter.

(iii) Do not measure a alone or a alone; measure them together (Mode IA), over at least the visible spectrum.

Alternatively :

(iv) Do not measure a alone or K alone; measure them together (Mode ICI), over at least the visible spectrum.

Alternatively:

(v) *Lo not measure* H(z,-)alone or h(z) alone; measure all four irradiances: H(z,±) and h(z,±) together (Mode II), or preferably N(z,•) (Mode IB), over at least the visible spectrum,

Of course with these don'ts go important positive observances of the usual kind, especially for alternatives (iv) and (v): recording of lighting conditions above the air water surface, the state of the air-water surface, the proximity and state of the bottom, the state of polarization, and so on.

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Problem Three: To Establish A Unified Automatic Computation Program for Prediction Computations and Data Reduction Computations in Geophysical Optics (the GEOVAC)

The theory of radiative transfer is now well founded with many excellent means of solution of the equations of the theory, as explained at length at appropriate points throughout the remainder of this work, or in Ref. [251], and in other works on the subject. In need at present are workable computer programs which will take a and o and boundary lighting conditions (either unpolarized or polarized) and yield internal radiance distributions throughout the medium of interest, regardless of its shape and size. In other words we envision a hardware realization of *the* Mode IA classification of natural optical media. Conversely, the computation programs should be able to convert experimental documentations of the unpolarized or polarized) radiance distributions (or at least irradiance quartets), as a function of wavelength and depth, into the appropriate determination of the inherent and apparent optical properties of the medium. In this way we can *also achieve* a hardware realization of the Mode IB (or, respectively, the Mode II) classification of natural optical . media. The applications of such a program-complex to the problems cited in the opening remarks of Sec. 1.4 are manifold, and many uses of such a program are undoubtedly yet to be conceived. The geophysical optics automatic variable computer—the 'GEOVAC'--program envisioned above will serve to tie together efforts on both Problems One and Two above, as well as help solve the everyday problems arising in the engineering applications of meteorologic and hydrologic optics'