imaginary paths in an optical medium is reminiscent of, and actually logically related to, the freedom of choice of the parameters x and z (Holding y fixed) in the statements of the principles of invariance (e.g., in Example 3 of Sec. 3.7) or the invariant imbedding relation (e.g., in Example 4 of Sec. 3.7).

9.6 Classification of Optical Properties

We conclude this chapter with a summary of the main optical properties introduced and developed in the present work. We shall classify the properties in several ways, according to the dimension of the medium to which they primarily apply, and according to whether they are local, global, inherent or apparent optical properties.

TABLE 1

Generic Inherent Optical Properties for One-, Two-, and Three-Dimensional Media

Dimension	Optical Property	Section
1 (paths)	$\mathbf{R}$, $\mathbf{T}$	3.17
2 (surfaces)	$r_{\pm}$, $t_{\pm}$	3.3
3 (solids)	$\mathcal{S}$	3.8

The term "generic," used in Table 1 to describe the listed optical properties, refers to their ability to generate all the secondary optical properties associated with the respective media, as explained in the various sections of Chapter 3. Thus, e.g., $\mathcal{S}(X;a,b)$ can generate all the standard reflectance and transmittance operators for plane-parallel media.

Below are tables of optical properties for plane-parallel (or generally one-parameter) optical media, the media of principal interest in hydrologic optics. The properties above each level may be used to deduce those on that level in the manner explained in the notes or references accompaning each table.

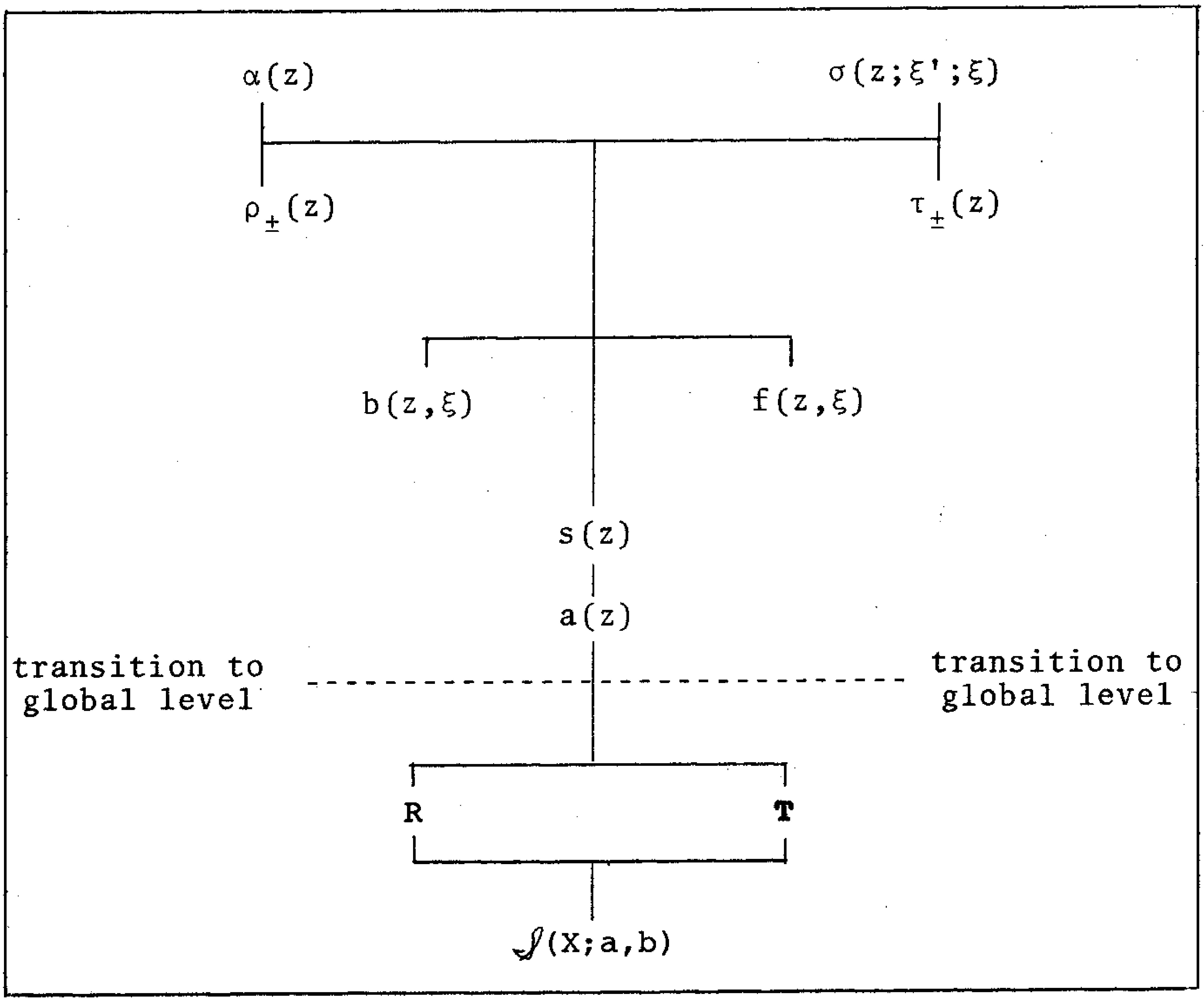
Several explanatory comments on Table 2 can be made. First, the operators $\rho_{\pm}(z)$ and $\tau_{\pm}(z)$ were defined in (3) and (4) of Sec. 7.1. The functions $f(z,\xi)$ and $b(z,\xi)$ are added to complement $f(z,\pm)$, $b(z,\pm)$ of Table 4 below, and are defined by writing:

$$\text{"}f(z,\xi)\text{"} \quad \text{for} \quad \int_{\Xi_+(\xi)} \sigma(z;\xi;\xi')\,d\Omega(\xi') \qquad (1)$$

$$\text{"}b(z,\xi)\text{"} \quad \text{for} \quad \int_{\Xi_-(\xi)} \sigma(z;\xi;\xi')\,d\Omega(\xi') \qquad (2)$$

TABLE 2

Local Inherent Optical Properties for Plane-Parallel Media



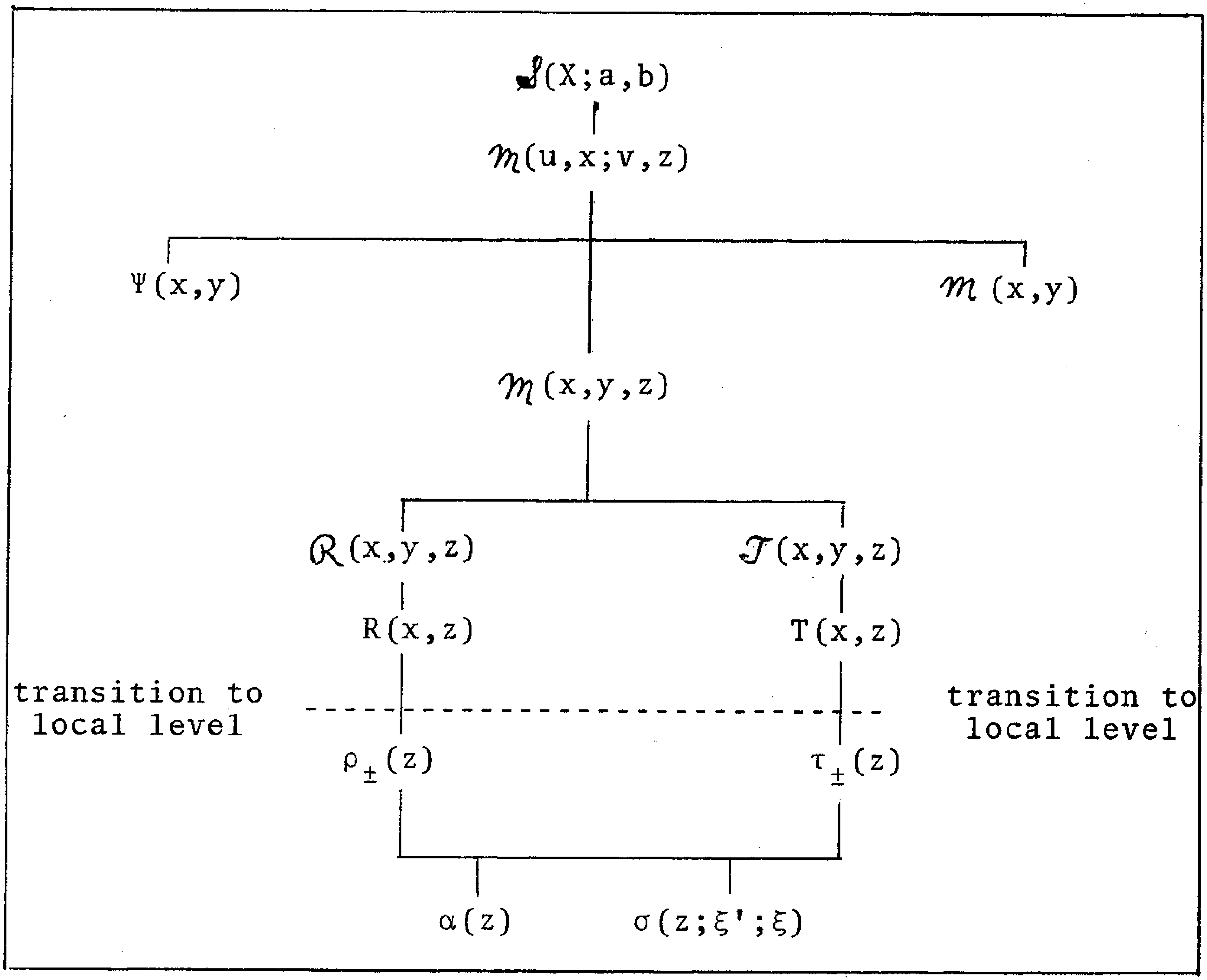
Here $\Xi_{\pm}(\xi)$ is the set of all directions ξ' such that $\xi \cdot \xi' > 0$ (for +) or $\xi \cdot \xi' < 0$ (for −). If the medium is isotropic, then $f(z,\xi)$ and $b(z,\xi)$ are independent of ξ.

The dashed line in the diagram of Table 2 represents the end of Table 2 and serves first of all to indicate the transition to the global level of Table 3, and is also included in order to show how Tables 2 and 3 are related, and finally to emphasize the fact that the pair (α, σ) is fundamental in the sense of Definition 3 of Sec. 9.1. The proof of this feature of (α, σ) is given in Sec. 22 and Sec. 23 of Ref [251]. The operators **R** and **T** are given in (5) and (12) of Sec. 3.17, and $\mathcal{J}$ is introduced in (6) of Sec. 3.8 and studied in Example 4 of Sec. 3.9.

Table 3 performs a double task of describing both the inherent and apparent global properties of plane-parallel media. The inherent properties are in force in Table 3 when radiance is being used; the apparent properties are in force when irradiance is being used. The operators

TABLE 3

Global Inherent or Apparent Optical Properties for Plane-Parallel Media



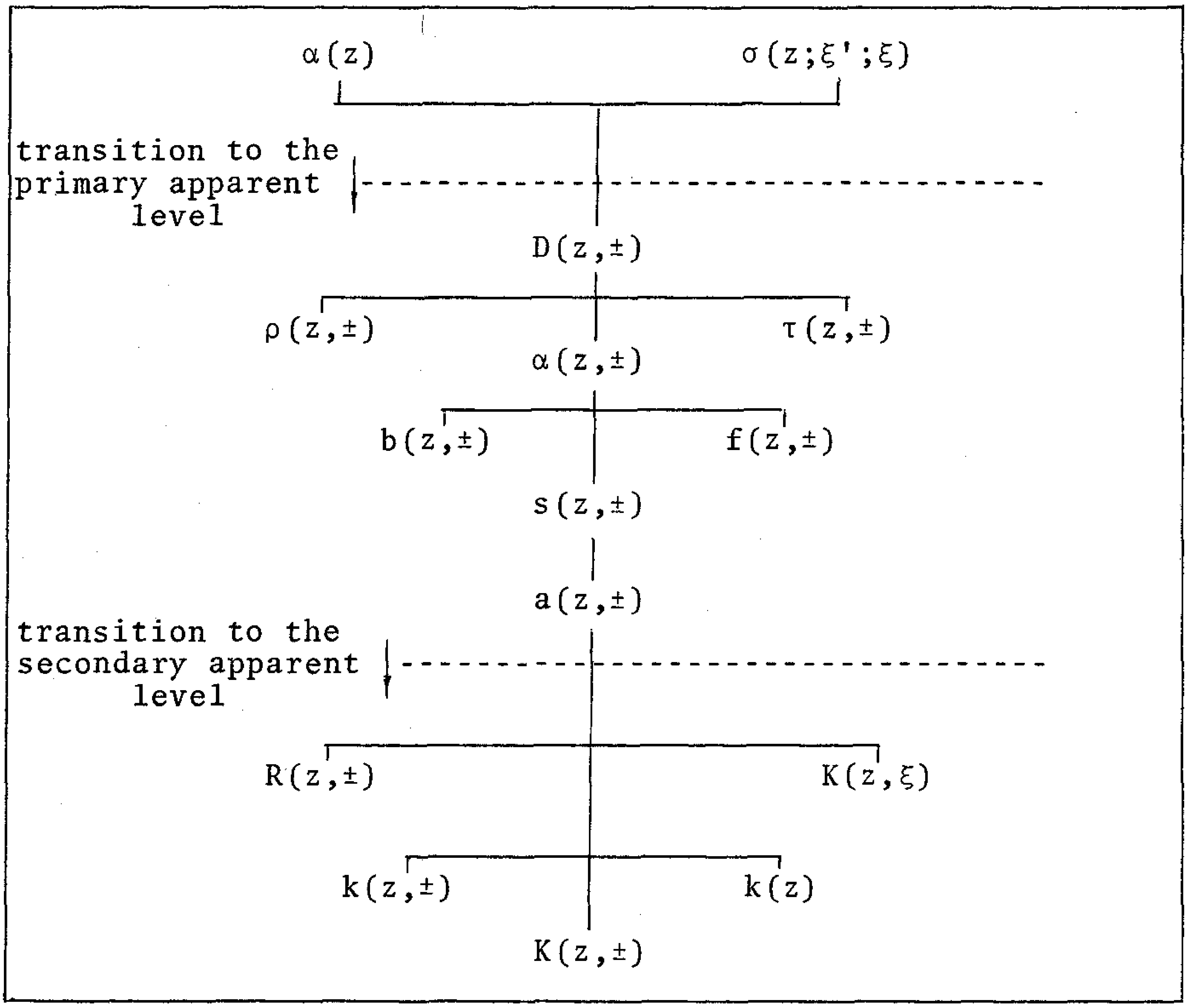
$\mathcal{M}(u,x;v,z)$ and $\mathcal{M}(x,y)$ are introduced in Examples 6 and 7 of Sec. 3.7. The operator $\Psi(x,y)$ is introduced in Example 3 of Sec. 3.9. The invariant imbedding operator $\mathcal{M}(x,y,z)$ is introduced in Example 4 of Sec. 3.7, along with its component operators $\mathcal{R}(x,y,z)$ and $\mathcal{T}(x,y,z)$. The standard operators $R(x,z)$ and $T(x,z)$ are introduced in Sec. 3.6. The transition to the local level is indicated by a dashed line which signals the end of Table 3 and is also included in the table to emphasize the fact that $\mathcal{D}(X;a,b)$ is a fundamental optical property (in the sense of Definition 3, Sec. 9.1). The proof that $\mathcal{D}(X;a,b)$ is a fundamental optical property is based on the derivations given in Sec. 125 of Ref. [251].

The optical properties of Table 4 are written for undecomposed irradiance fields. By appending star or circle superscripts,* the properties for diffuse or residual

*The basis for this notational device is described in Sec. 8.4.

TABLE 4

Local Apparent Optical Properties for Plane-Parallel Media



irradiance are obtained. In the interests of brevity, these additional concepts are not diagrammed. The primary level of optical properties in Table 4 for the most part parallel their inherent counterparts in Table 2. They may be thought of as hybrids resulting from the union of inherent optical properties and the light field. The secondary apparent level summarizes some optical properties which are on the borderline between local and global properties. For example, $R(z\ -)$ is the reflectance at level z, and thus, being defined at a point at level z, is ostensibly local in nature. However, the value of $R(z,-)$ is intimately tied to the values of the light field and the inherent optical properties of the medium at all levels above and below level z. The classical counterparts to the secondary optical properties of Table 4 arose in the solutions of the one-D two-flow models of the light field. The secondary properties appearing in Table 4 are the exact, directly observable counterparts to the earlier one-D model concepts. The various primary properties occurring in Table 4 are defined throughout Chapter 8, the secondary properties (including $K(z,\xi)$) are defined in Sec. 9.2.

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