A METHOD OF COMPUTING THE EMERGENT RADIATION BY THE ATMOSPHERE IN THE REGION RANGING FROM ULTRAVIOLET TO INFRARED

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Abstract. A method of computing the diffuse reflection and transmission radiation by an inhomogeneous, plane-parallel planetary atmosphere with internal emission source is discussed by use of the adding method. If the atmosphere is simulated by a number of homogeneous sub-layers, the radiation diffusely reflected or transmitted by the atmosphere can be expressed in terms of the reflection and transmission matrices of the radiation of sub-layers. The diffusely transmitted radiation due to the internal emission source can be also easily computed in the same manner. These equations for the emergent radiation are in a quite general form and are applicable to radiative transfer in the atmosphere in the region from ultraviolet to infrared radiation. With this method, the tiresome treatment due to the polarity effect of radiation is overcome.

1. Introduction

It is evident that remote sensing techniques from Earth satellites have certain advantages particularly where ground based data is not readily available. Hence these techniques are being used as a tool for determining temperature fields (Smith, 1972) and wind vector fields (Leese et al., 1971) of the atmosphere. More recently, the increased demand for hydrological information such as ice and snow covered areas (Barnes et al., 1972; Wiesnet, 1974; Strong et al., 1971; McClain, 1973) as well as the growing state of vegetation (Coulson and Reynolds, 1971) has resulted in the use of remote sensing from Earth satellites carrying high-resolution radiometers. However, there are frequent ambiguities in the data obtained by these methods even after enhancement techniques are adopted in order to improve the data. The major difficulties are due to cloud contamination in the optical field of view of data taken from the satellites, as well as optically active constituents inherent in the atmosphere. This has resulted in a trend to use a combination of infrared and visible data to provide more independent information than can be deduced from data taken in one single channel. In fact, the use of the near infrared data (3.6–4.2 𝜇) in combination with the visible spectrum data (0.7–1.3 𝜇) appears to permit the detection of thawing snow and ice packs as demonstrated in the experimental Nimbus 3 meteorological satellite (Strong et al., 1971). More recently, the spectral interval of 10.5–12.5 𝜇 as well as the visible channel (0.6–

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0.7 μ) is now operationally available from the very high resolution radiometer (VHRR) system of the ITOS series of meteorological satellites.

In this paper, the main interest is to develop computation procedures for the emergent radiation of the inhomogeneous plane-parallel atmosphere in the region from ultraviolet to infrared radiation. The internal radiation of the atmosphere is partly due to the temperature field as defined by the Local Thermodynamical Equilibrium and partly due to the scattering thereafter. Moreover, the atmosphere is bounded by the surface where the partial emission and reflection of radiation is known to take place. The external illumination due to the solar flux is also taken into account.

It is shown that the adding method (Takashima, 1974) can be extended to compute the upwelling and downwelling radiation of a model atmosphere. The troublesome treatment due to the polarity effects of radiation is overcome by the method. By applying the adding method, the atmosphere is simulated by a number of homogeneous sub-layers and the radiation reflected and transmitted diffusely by the atmosphere can be expressed in terms of those of the composite layers (see Figure 1).

Fig. 1. Diagram showing the symbols used for solution of the transfer problem. Directional parameters are abbreviated for simplicity.

2. Derivation of Equation

Consider a plane parallel layer of optical thickness τ which is illuminated by the parallel radiation from above with flux πF₀ per unit area perpendicular to the incident beam. The layer is bounded by a reflecting surface on the bottom (see Figure 1). On applying the adding method, the atmosphere is simulated by a number of homogeneous sub-layers. By increasing the number, it gradually approaches the inhomogeneous atmosphere. Let us choose two arbitrary sub-layers from the bottom of the atmosphere with the optical thickness x₁ and x₂, respectively. The layers x₁ and x₂ are assumed to be homogeneous. The diffuse reflection and transmission matrices (4 × 4 matrices) of each layer are given and denoted by the symbols of S(x₁), T(x₁) and S(x₂), T(x₂), respec-