Prediction of emission and scattering coefficient from cloud layer contain gases ,ice and water vapor from optical and infrared band

Abstract Now a day the effect of cloud layer in ice and water vapor on the propagation of electromagnetic waves has become a subject of interest. Hence considerable attention has been devoted to evaluate the influence of natural occurring obscurant on the performance of electromagnetic wave (optical, infrared and millimeter wave) propagation. It may be mentioned that like other precipitation sand and dust particles present in the atmosphere ice, sheet, water vapor, different gases, also effect the propagation of electromagnetic waves. These particles affect the phase and amplitude of the wave during propagation. In this paper an attempt has been made to evaluate the scattering Aledo, coefficient, reflection coefficients from cloud layer using Radiative Transfer Model at optical, infrared radiation. After estimation of reflection coefficient and scattering coefficients, calculate temperature brightness with wavelength for different effective radius of particles of gases such as ozone, carbondiodixe, ammonia, water vapor .

KEY WORDS: EMISSON COEFFICENT, ANGLE OF INCIDENCE, OPTICAL THERMAL AND REFLECTED INFRARED FREQUENCY, MOISTURE AND DEPTH OR THICKNESS, MODIS BANDS

1. Introduction

In this paper an attempt has been made for estimation of emissivity of optical, infrared, radiation signal using the MODIS band from cloud layer. The expression for emissivity and reflection coefficients from cloud layer which contain moisture, ice particles , sleet , rain , water developed have been developed both for vertical and horizontal polarization. Reflection and Emission coefficient depends on frequency, angle of incidence, dielectric constant of water , moisture water content and thickness ,surface roughness, chemical compositions, physical temperature , atmospheric temperature . It is found that Reflection coefficient of optical and infrared signal decreases with increases in wavelength an increases effective radius of particle. And scattering albedo also decreases with increases in wavelength increase with angle of incidence and visibilities. The dielectric constant for real and imaginary part increases with moisture content. At last also find temperature brightness from cloud layer for different gases , which has different values depend upon polarization properties . The intent of this document is to present algorithms for inferring certain optical and thermodynamical properties of cloud layers, specifically, optical thickness, effective particle radius, and particle phase from multi wavelength reflected solar and emitted thermal radiation measurements. It is well known that clouds strongly modulate the energy balance of the Earth and its atmosphere through their interaction with solar and terrestrial radiation, as demonstrated both from satellite observations and from modeling studies. However, clouds vary considerably in their horizontal and vertical extent, in part due to the circulation pattern of the atmosphere with its requisite updrafts and downdrafts, and in part due to the distribution of oceans and continents and their numerous and varied sources of cloud condensation nuclei (CCN). A knowledge of cloud properties and their variation in space and time, therefore, is crucial to studies of global climate change (e.g., trace gas greenhouse effects), a corresponding cloud feedback working to enhance global warming. The main objective of this work is the development of routine methods for simultaneously retrieving the cloud optical thickness and effective particle radius from daytime multi wavelength reflected solar and emitted thermal radiation measurements. Retrieval of cloud particle phase from visible and near-infrared solar reflection measurements will also be discussed. The scattering albedo , temperature brightness and reflection coefficient is obtained by help of Radiative Transfer model , shows energy transfer between surface and clouds , and top of cloud which has higher temperature sue to extent solar radiation ,. These coefficients predict by optical and infrared wavelengths at different angle of incidence generally these values collaborate with MODIS data which has six bans of range MODIS is a 36-band scanning spectroradiometer. Four of these visible (0.645 mm) and near-infrared (1.64, 2.13, and 3.75 mm) spectral bands will be used in our daytime shortwave cloud retrieval algorithm over land surfaces, with 0.858 or 1.240 mm replacing 0.645 mm over ocean and bright snow/sea ice surfaces, respectively. Other bands in the thermal region, such as the 8.55, 11.03, 12.02, 13.335, 13.635, 13.935 and 14.235 mm bands, will be used for cloud cover and cloud top properties (including cloud top altitude, cloud top temperature and thermodynamic phase) In addition, the 11.03 μm band will be used to make the thermal emission correction to the 3.75 μm band during the day. The 0.645, 2.13 and 3.75 μm bands will be used to retrieve the cloud optical thickness and effective particle radius over land (with 0.645 μm replaced by 0.858 μm over oceans and 1.24 μm over snow and sea ice surfaces); a combination of the 0.645, 1.64, and possibly the 2.13 μm bands will be used for cloud thermodynamic phase determination.

2.. Theoretical description

Radiative Transfer Model

In order to describe the characteristics of spectra measured by a passive infrared spectrometer, a model may be used in which the atmosphere is divided into plane-parallel Homogeneous layers along the optical path. In many cases a model with three layers is sufficient to describe the basic characteristics of the spectra (Figure 1). Radiation from the background, for example the sky or a surface (background layer), propagates through the vapor cloud (cloud layer, a mixture of the released molecules and air), and the atmosphere between the cloud and the spectrometer (atmospheric layer). The radiation containing the signatures of all layers is measured by the spectrometer. The cloud and atmospheric layers are considered homogeneous with regard to all physical and chemical properties. Application of the three layer model[6] yields

$$L_S = (1-\tau_{at})B_{at} + \tau_{at}\left[(1-\tau_c)B_c + \tau_c L_b\right] \qquad \text{.............................}1$$

for the spectral radiance at the entrance aperture of the spectrometer L_S. Here, τ_{at} is the transmittance of the atmosphere between the spectrometer and the cloud, B_{at} is the spectral

Radiance of a blackbody at the temperature of the atmosphere, T_{at}, τ_c is the transmittance of the cloud, and B_c is the spectral radiance of a blackbody at the temperature of the cloud, T_c. L_b is the radiance that enters the layer of the cloud from the background. The quantities in Equation (1) are frequency-dependent. Because the scattering coefficient in the infrared spectral region is small under many measurement conditions, the contribution of scattering is neglected in this model. If the temperatures of the cloud layer and the atmospheric layer are equal, Equation (1)
can be simplified:

$$L_S = B_{at} + \tau_{at}\,\tau_c\left(L_b - B_{at}\right). \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 2$$

To retrieve the cloud optical thickness and effective particle radius, a radiative transfer model is first used to compute the reflected intensity field. It is convenient to normalize the reflected intensity (radiance) $I_\lambda(0, -\mu, \phi)$ in terms of the incident solar I is the measured intensity at the top-of-atmosphere, $I_{\text{cloud-top}}$ is the cloud top intensity, including surface effects, in the absence of an atmosphere, and t_{atm} is the above-cloud transmittance in either the μ or μ_0 directions flux F_0at different wavelength (λ), such that the reflection function $R_\lambda(\tau_c, r_e; \mu, \mu_0, \phi)$ is defined

by $$R(\tau_c', r_e; \mu, \mu_0, \phi) = I_\lambda(0, -\mu, \phi)\, r_e\, \tau_c' \,/\, \mu_0 F_0(\lambda) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

where τ_c is the total optical thickness of the atmosphere (or cloud), r_e the effective particle radius, defined by (Hansen and Travis 1974)

$$r_e = r^3 n(r)\,dr \,/\, r^2 n(r)\,dr, \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 4$$

where $n(r)$ is the particle size distribution and r is the particle radius, μ_0 the cosine of the solar zenith angle θ_0, μ the absolute value of the cosine of the zenith angle θ, measured with respect to the positive τ direction, and ϕ the relative azimuth angle between the direction of propagation of the emerging radiation and the incident solar direction. When the optical thickness of the atmosphere is sufficiently large, numerical results for the reflection function must agree with known asymptotic expressions for very thick layers (van de Hulst 1980). Numerical simulations as well as asymptotic theory show that the reflection properties of optically thick layers depend essentially on two parameters, the scaled optical thickness τ_c'

$$\tau_c' = (1 - \omega_0 g)\tau_c \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

where g is the asymmetry factor and ω_0 the single scattering albedo of a small volume of cloud air.

Putting the value of r_e , τ_c' in equ 3 we get reflection coefficient of optical and infrared signal from cloud layer.

$$R(\tau_c', r_e; \mu, \mu_0, \phi) = I_\lambda(0, -\mu, \phi)\, r^3 n(r)\,dr \,/\, r^2 n(r)\,dr\,(1 - \omega_0 g)\tau_c \,/\, \mu_0 F_0(\lambda) \qquad \ldots\ldots\ldots 6$$

Then transmittance of signal is given as τ_c from the cloud is

$\tau c = 1- R(\tau_{c}', r_{e}; \mu, \mu_{0}, \phi)$ ……………………….7

Now then we calculate scattering Aledo from cloud thickness layer at different wavelength at solar zenith angle of 10 degree is defined as

$\omega 0 = 1+\tau c' / \tau c \ g$ ………………………………..8

Putting he value of τc in 8

$\omega 0 = 1+\tau c' / 1- R(\tau_{c}', r_{e}; \mu, \mu_{0}, \phi) \ g$

$\omega 0 = 1+\tau c' / 1- I\lambda(0, -\mu, \phi) \ r^{3} n(r) dr / r^{2} n(r) dr \ (1 - \omega 0 g)\tau c \ / \mu_{0} F_{0}(\lambda) \ g$

…………………………9

Putting in radiative transfer equation we ret transfer of heart and energy between land, surface, cloud layer, top of clouds, and different gases.

Now calculate for Brightness temperature from cloud layer as a function of wavelength for nadir observations and for various values of the effective radius of cloud droplets, where the cloud optical thickness tc(0.75 mm) = 5 for all cases. Results apply to water clouds having a modified gamma distribution embedded in a midlatitude summer atmosphere with cloud top temperature Tt = 14°C, cloud base temperature Tb = 17°C, and an underlying surface temperature Ts = 21°C

$LS = Bat + \tau_{at} \ \tau_{c} \left(Lb - Bat\right).$

Brightness temperature $Bat = LS- \tau_{at} \ \tau_{c} Lb/1+ \tau_{at} \ \tau_{c}$ ………………………….10

$Bat = LS- \tau_{at} \ 1- R(\tau_{c}', r_{e}; \mu, \mu_{0}, \phi) \ Lb/1+ \tau_{at} \ 1- R(\tau_{c}', r_{e}; \mu, \mu_{0}, \phi)$

For ice particles:

Cloud is composed of 50% bullet rosettes,30% hollow columns, and 20% solid plate ice crystals From ice particles present in cloud layer causes volume scattering, an volume extinction coefficient is given as $d_{p} = ke^{-1}$ ……………………………….11

K is sum of absorption and scattering coefficients the penetration depth is given by

stiles $dp = \lambda\sqrt{\varepsilon}/\acute{\varepsilon}$ ……………………..12

Volume scattering is given from ice particles,

$\sigma^{vol}_{vv} = 0.75f \ L \cos\theta_{i}[1-\exp(-2k_{e}d/\cos\theta_{t})]$ …………………………..13

where L denote the width and the maximum dimension of an ice crystal, respectively, and n*(L)* is the size distribution as a function of *L*, *f is frequency* θ_i is angle of incidence , θ_t is angle of transmission .

3.. Result and discussion In this paper an attempt has been made to evaluate the scattering, reflection coefficients from cloud layer using Radiative Transfer Model at optical, infrared radiation. After estimation of reflection coefficient and scattering coefficients, calculate temperature brightness with wavelength for different gases. The sensor-measured intensity at visible wavelengths (0.66 μm) is primarily a function of cloud optical thickness, whereas near-infrared intensities (1.6, 2.1, and 3.7 μm) are sensitive both to optical thickness and, especially, cloud particle size. As a consequence, Rayleigh scattering in the atmosphere above the cloud primarily affects the cloud optical thickness retrieval since the Rayleigh optical thickness in the near-infrared is negligible. Because the Rayleigh optical thickness in the visible wavelength region is small (about 0.044 at 0.66 μm), it is frequently overlooked in retrieving cloud optical thickness for to investigate the Rayleigh scattering effects on cloud optical thickness retrievals . from fig 1, eq 6 it is observed that reflection coefficient of signal decreases with increases wavelength up to infrared region .We simplified the air-cloud system as a two-layer atmosphere with molecules above the cloud, and carried out simulations with an adding-doubling code as from graph temperature brightness has different values for different molecules varies with wavelength , its values for water has high at 5-6 micrometer , for carbon dioxide it has 4-5 micrometer . , for ozone it has high 10-12 micrometers from equ 10 fig 3 it is observed that temperature brightness fro atmosphere cloud layer top cloud layer increases with wavelength . , For ice crystal two thing come from equ 13 fig 4 that with increases in frequency, back scattering or volume scattering from ice particles increases, due to lambertian surface and with increases in angle of incidence the back scattering decrsses from cloud model. , and from equ 9 fig 2 it is observed that second scattering coefficients decreases with increases in wavelength at different effective particle thickness.

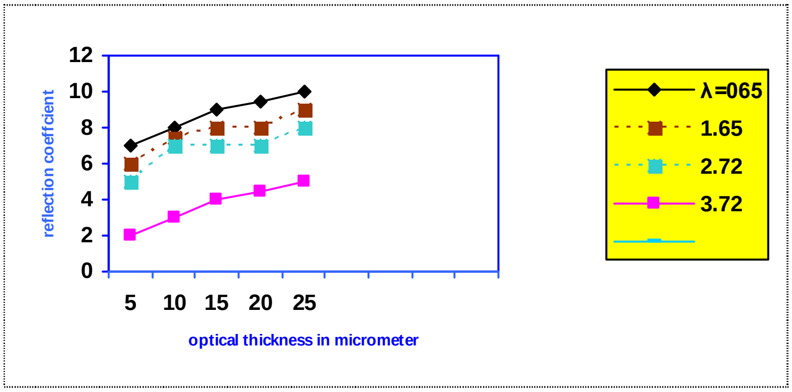

Fig 1 shows variation of reflection coefficient and optical effective radius of particle at different wavelength

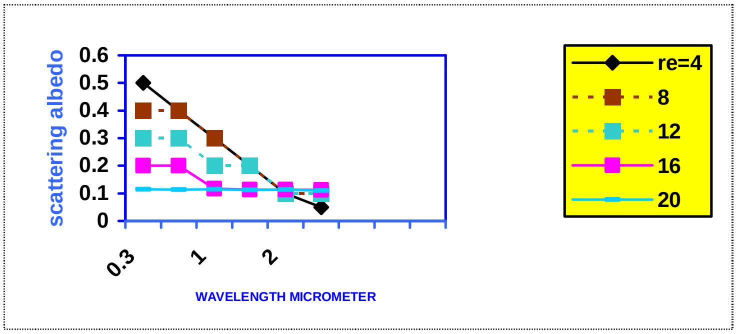

Fig 2 shows variation of scattering albedo in db and wavelength at different effective radius of particles re in micrometer.

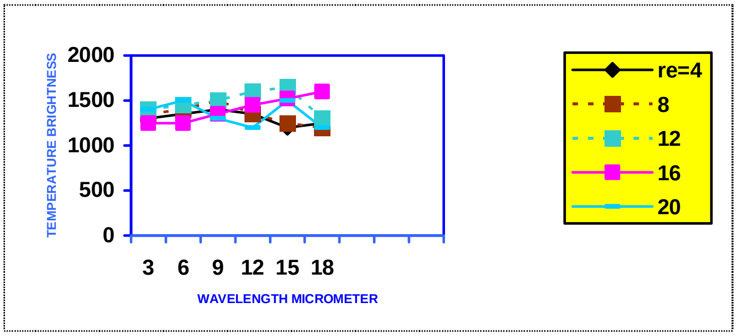

Fig 3 shows variation of temperature brightness and wavelength at different effective radius of particles re in micrometer.

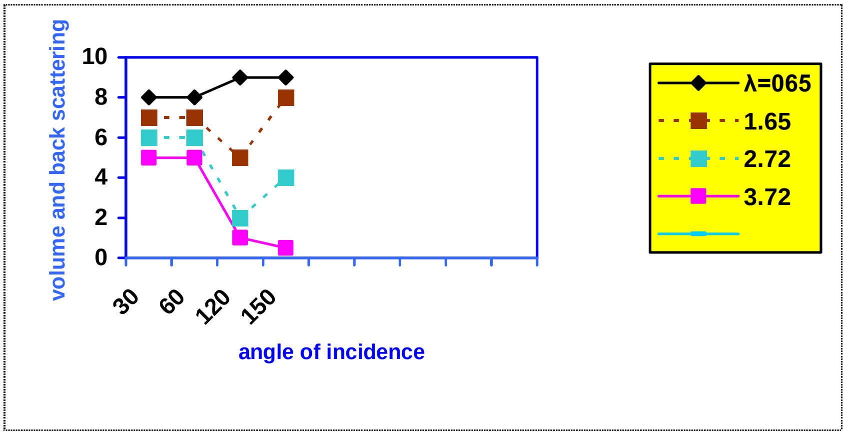

Fig 4.shows variation of scattering coefficient and optical effective radius of particle at different wavelength

References

Harig, R., Matz, G., „Toxic Cloud Imaging by Infrared Spectrometry: A Scanning FTIR System for Identification and Visualization," Field Analytical Chemistry and Technology 5 (1-2), 75-90 (2001).

Rothman, L., Rinsland, C., Goldman, A., Massie, S., Edwards, D., Flaud, J., Perrin, A., Camy-Peyret, C., Dana, V., Mandin, J., Schroeder, J., McCann, A., Gamache, R., Wattson, R., Yoshino, K., Chance, K., Jucks, K., Brown, L., Nemtchinov, V., Varanasi, P., „The HITRAN Molecular Spectroscopic Database and HAWKS (HITRAN Atmospheric Workstation): 1996 Edition," Journal of Quantitative Spectroscopy and Radiative Transfer 60, 665-710 (1998)

.Smith, H.J.P., Dube, D.J, Gardner, M.E., Clough, S.A., Kneizys, F.X., Rothman, L.S., „FASCODE- Fast Atmospheric Signature Code (Spectral Transmittance and Radiance)," Air Force Geophysics Laboratory Technical Report AFGL-TR-78-0081, Hanscom AFB, MA (1978).

Ackerman, S., K. Strabala, P. Menzel, R. Frey, C. Moeller, L. Gumley, B. Baum, C. Schaaf, and G. Riggs, 1997: *Discriminating Clear-Sky from Cloud with MODIS: Algorithm Theoretical Basis Document (MOD35)*. Algorithm Theoretical Basis Document ATBD-MOD-06, NASA Goddard Space Flight Center, 125 pp.

Arking, A., 1964: Latitudinal distribution of cloud cover from TIROS III photographs. *Science*, **143**, 569–572.

J. D. Childs, 1985: Retrieval of cloud cover parameters from multispectral satellite images. *J. Climate Appl. Meteor.*, **24**, 322–333

Windpassinger, R., "Quantitative Analysis of flue gas FTIR-spectra employing a new mathematical method to determine the instrumental line shape," in *Spectroscopic Atmospheric Environmental Monitoring Techniques*, Klaus Schäfer, Editor, Proc. SPIE 3493, 64-70 (1998).Bevington, P. R., 1969: *Data Reduction and Error Analysis for the Physical Sciences*.McGraw-Hill, 336 pp.

Treut, Z. X. Li, X. Z. Liang, J. F. B. Mitchell, J. J. Morcrette, D. A. Randall, M. R. Riches, E. Roeckner, U. Schlese, A. Slingo, K. E. Taylor, W. M. Washington, R. T. Wetherald and I. Yagai, 1989: Interpretation of cloud-climate feedALGORITHM THEORETICAL BASIS DOCUMENT, OCTOBER 1996 70back as produced by 14 atmospheric general circulation models. *Science*, **245**,513–516.

Chu, A., K. Strabala, R. Song, S. Platnick, M. Wang and S. Mattoo, 1997: *MODIS Atmosphere QA Plan*, NASA Goddard Space Flight Center, 43 pp.

Cline, A. K., 1974: Scalar- and planar-valued curve fitting using splines under tension. *Comm. Assoc. Comput. Mach.*, **17**, 218–220.

Curran, R. J., H. L. Kyle, L. R. Blaine, J. Smith and T. D. Clem, 1981: Multichannel scanning radiometer for remote sensing cloud physical parameters. *Rev. Sci. Instrum.*, **52**, 1546–1555
.

M. L. C. Wu, 1982: Skylab near-infrared observations of clouds indicating supercooled liquid water droplets. *J. Atmos. Sci.*, **39**, 635–647.

DAO, 1996: *Algorithm Theoretical Basis Document for Goddard Earth Observing SystemData Assimilation System (GEOS DAS) with a focus on Version 2*. ATBDDAO-01, NASA Goddard Space Flight Center, 131 pp.

Downing, H. D., and D. Williams, 1975: Optical constants of water in the infrared. *J. Geophys. Res.*, **80**, 1656–1661.

Durkee, P. A., 1989: Observations of aerosol-cloud interactions in satellite detected visible and near-infrared radiance. *Proc. Symposium on the Role of*

Clouds in Atmospheric Chemistry and Global Climate, American Meteorological Society, Anaheim, CA, 157–160.

Foot, J. S., 1988: Some observations of the optical properties of clouds. I: Stratocumulus. *Quart. J. Roy. Meteor. Soc.*, **114**, 129–144.

Grainger, R. G., 1990: The calculation of cloud parameters from AVHRR data. *Ph.D. Dissertation*, University of Auckland, New Zealand, 188 pp.

Hale, G. M., and M. R. Querry, 1973: Optical constants of water in the 200-nm to 200-μm wavelength region. *Appl. Opt.*, **12**, 555–563.

Han, Q., W. B. Rossow and A. A. Lacis, 1994: Near-global survey of effective droplet radius in liquid water clouds using ISCCP data. *J. Climate*, **7**, 465–497.

W. Rossow, R. Welch, A. White and J. Chou, 1995: Validation of satellite retrievals of cloud microphysics and liquid water path using observations from FIRE. *J. Atmos. Sci.*, **52**, 4183–4195.

Hansen, J. E., and J. B. Pollack, 1970: Near-infrared light scattering by terrestrial clouds. *J. Atmos. Sci.*, **27**, 265–281.

L. D. Travis, 1974: Light scattering in planetary atmospheres. *Space Sci. Rev.*, **16**, 527–610.

Irvine, W., M., and J. B. Pollack, 1968: Infrared optical properties of water and ice spheres. *Icarus*, **8**, 324–360.

Kaufman, Y. J., and T. Nakajima, 1993: Effect of Amazon smoke on cloud microphysics and albedo. *J. Appl. Meteor.*, **32**, 729–744.

King, M. D., 1981: A method for determining the single scattering albedo of clouds through observation of the internal scattered radiation field. *J. Atmos. Sci.*, **38**, 2031–204.

1987: Determination of the scaled optical thickness of clouds from reflected solar radiation measurements. *J. Atmos. Sci.*, **44**, 1734–1751.

L. F. Radke and P. V. Hobbs, 1990: Determination of the spectral absorption of solar radiation by marine stratocumulus clouds from airborne measurements within clouds. *J. Atmos. Sci.*, **47**, 894–907.

Y. J. Kaufman, W. P. Menzel and D. Tanré, 1992: Remote sensing of cloud, aerosol and water vapor properties from the Moderate Resolution Imaging Spectrometer (MODIS). *IEEE Trans. Geosci. Remote Sens.*, **30**, 2–27.

W. P. Menzel, P. S. Grant, J. S. Myers, G. T. Arnold, S. E. Platnick, L. E. Gumley, S. C. Tsay, C. C. Moeller, M. Fitzgerald, K. S. Brown and F. G. Osterwisch, 1996: Airborne scanning spectrometer for remote sensing of cloud, aerosol, water vapor and surface properties. *J. Atmos. Oceanic Technol.*, **13**, 777–794.