Figure captions

Fig.2 Imaginary part of the refractive index of water and ice.
Fig.3 The extinction coefficient of a cloudy medium with water droplets, characterized by the PSD (2.3) at $a_{ef} = 4\mu m$, $\mu = 6$. The value of C_w is equal to 0.1g/m^3.

Fig.4 The spectral dependence $B(\lambda)$, obtained for the same conditions as in Fig.3.

Fig.5. The probability of photon absorption, obtained for the same conditions as in Fig. 3. The results for the effective radius $a_{ef} = 16\mu m$ are also shown.

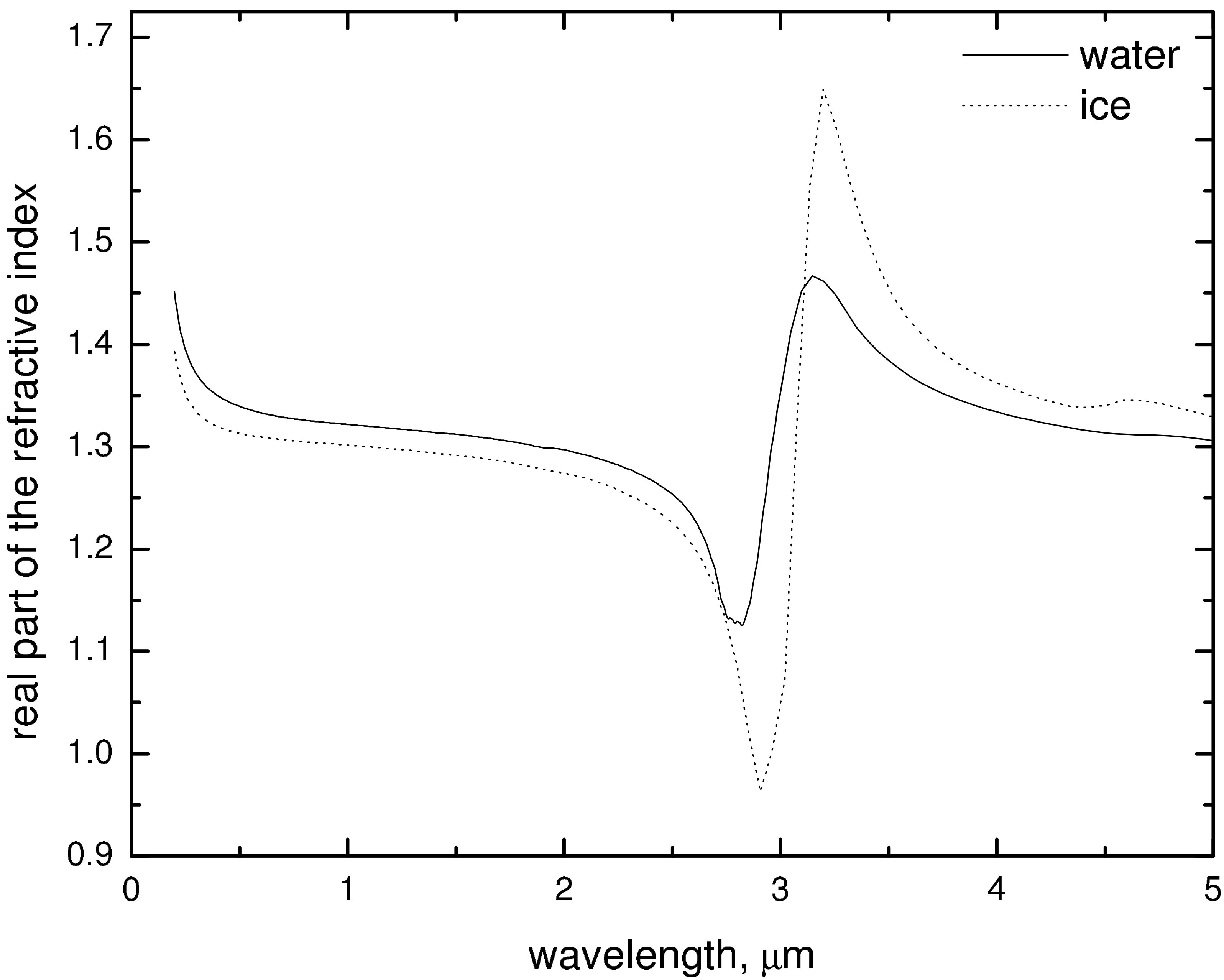
Fig.6. The error of the geometrical optics approximation for the probability of photon absorption, obtained from data, presented in Fig.5 for effective radii 4 and 16 micrometers. Data for the effective radius 6 micrometers are also shown.
Fig. 7. Phase functions of water clouds, obtained from the Mie theory for the same conditions as in Fig.3. The data for a_{ef} equal to 6 μm and 16 μm are also given for the comparison.

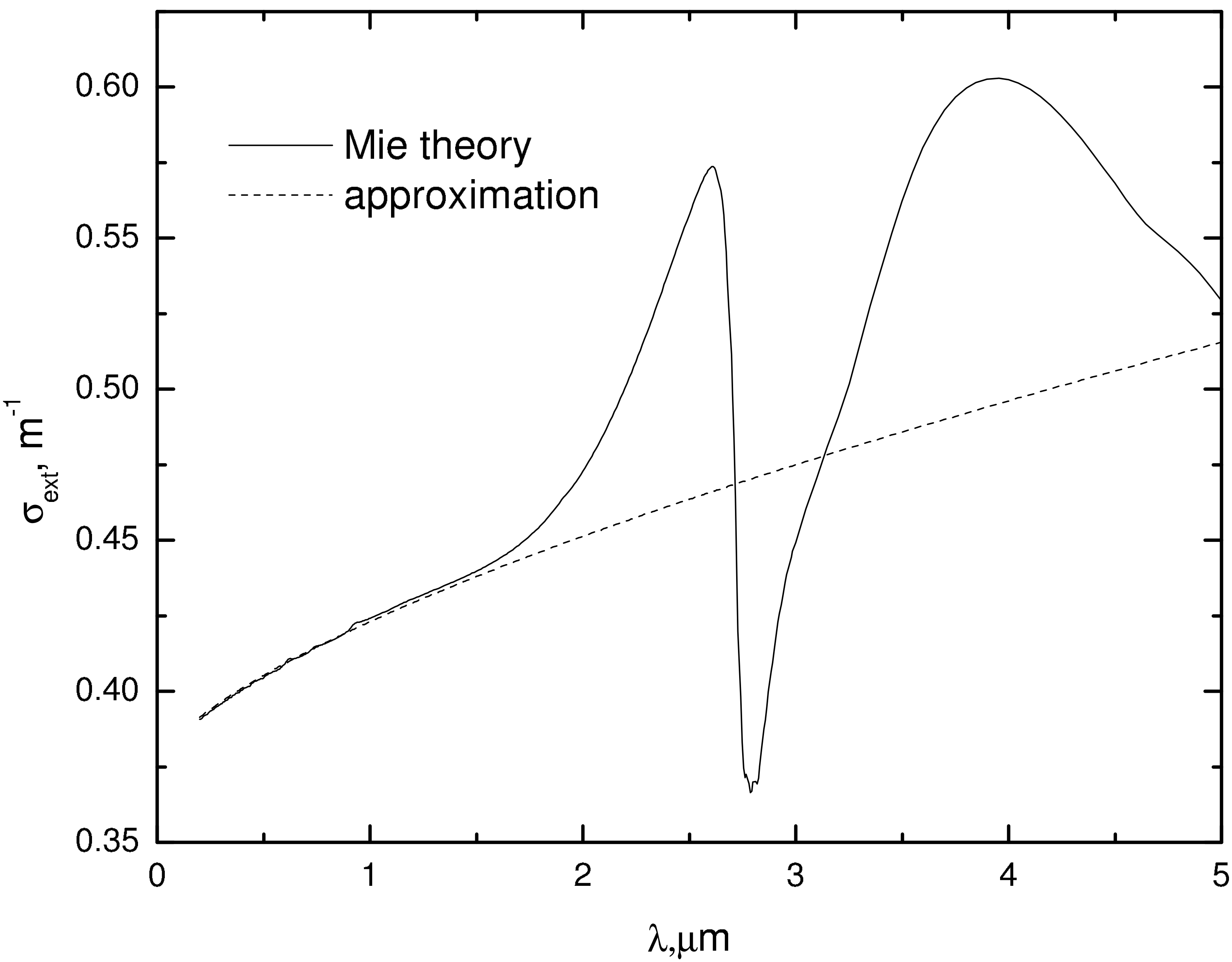
Fig. 8. The coefficients a_s, obtained for the same conditions as in Fig.3. Data for a_{ef} equal to 6 μm are also shown.

Fig.9. The spectral dependence $C(\lambda)$, obtained for the same conditions as in Fig.3.

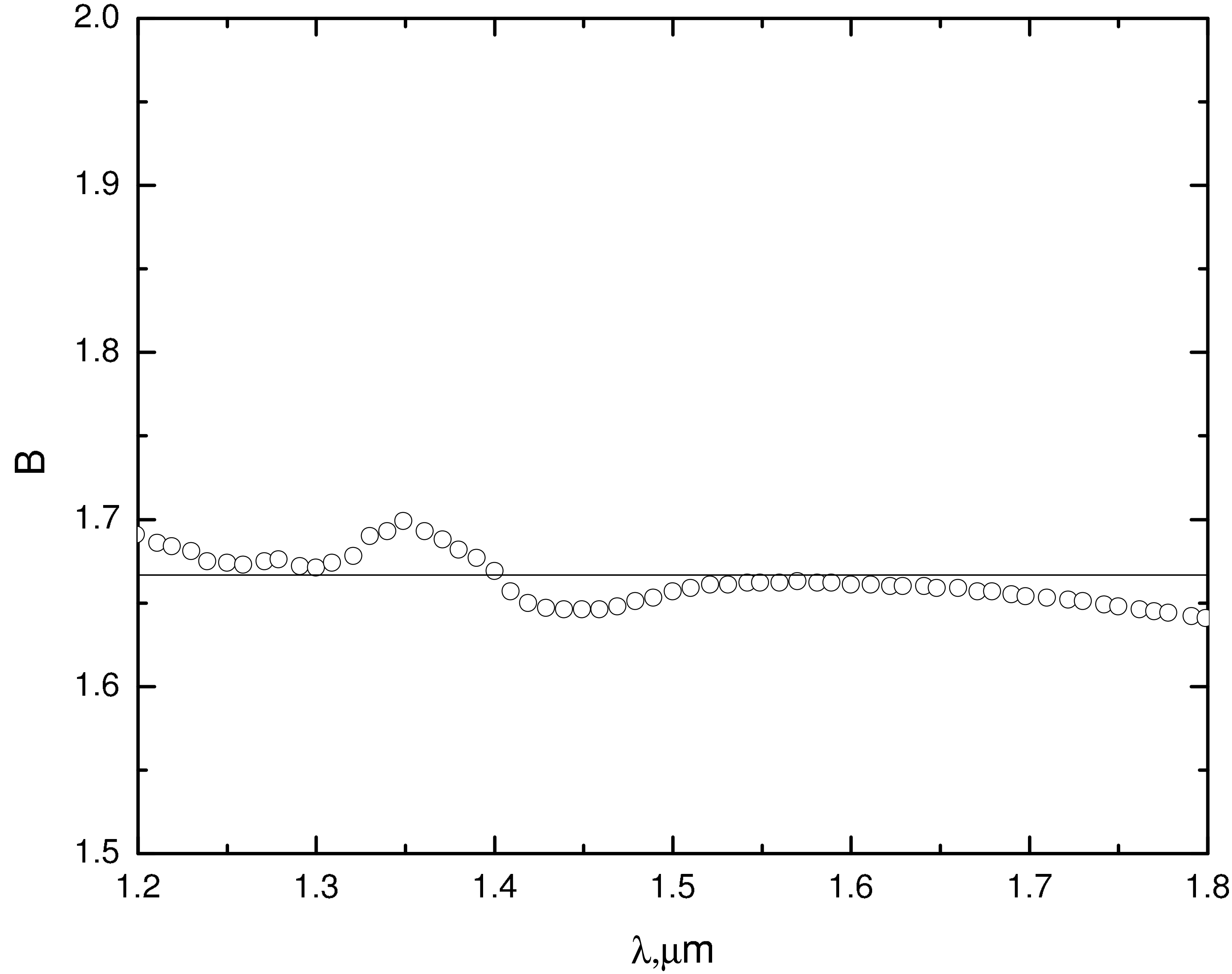
Fig.10. The asymmetry parameter, obtained for the same conditions as in Fig. 3. The results for the effective radius $a_{ef} = 6\mu m$ are also shown.

Fig.11. The error of the geometrical optics approximation for the asymmetry parameter, obtained from data, presented in Fig.10 for effective radii 4 and 6 micrometers.
Fig.12 . Phase functions of hexagonal ice cylinders with the aspect ratio(length/size of the side of the hexagonal cross section) equal to 5.88 and fractal particles in random orientation at the wavelength 0.5 μm. Only the geometrical optics contribution of both phase functions is shown.
Fig. 13. The reflection function of an idealized semi-infinite nonabsorbing cloud $R_\infty^0(0, \vartheta_0, 0)$ obtained from the exact radiative transfer code (Mishchenko et. al., 1999) and approximation (4.5) at the wavelength $\lambda = 0.65\mu m$ and the effective radii of droplets $a_{ef} = 6$ and $16\mu m$. It is assumed that particles in a cloud are characterized by the gamma particle size distribution(2.3) with the parameter $\mu = 6$.
Fig.14. The escape function, calculated with exact radiative transfer code for the Heyney-Greenstein phase function at g = 0.75, 0.8 and 0.9 (Yanovitskij, 1997) and with approximation, given by Eq. (4.10).
Fig. 15a. The dependence of the reflection function of a cloudy layer on the optical thickness according to Eqs. (4.6) (at λ=0.65μm) and (4.30) (at λ=1.55μm) for $a_{ef} = 6\mu m$, $\vartheta = 7^\circ$, $\vartheta_0 = 49^\circ$, φ=0° as compared to exact radiative transfer computations. It is assumed that particles in a cloud are characterized by the gamma particle size distribution (2.3) with the parameter $\mu = 6$.
Fig 15b. The errors of approximations , given by Eqs. (4.6) (at λ=0.65μm) and (4.30) (at λ=1.55μm) for $a_{ef} = 6\mu m$, $\vartheta = 7^\circ$, $\vartheta_0 = 49^\circ$, φ=0° as compared to exact radiative transfer computations.
Fig.16. The frequency of registration of different optical thicknesses of cloudy media, obtained from satellite and ground measurements as presented by Trishchenko et al.(2001)
Fig.17. The spectral dependence of the reflection function of cloudy media for the nadir observation and the solar angle equal to 60 degrees. Clouds are composed of water or ice

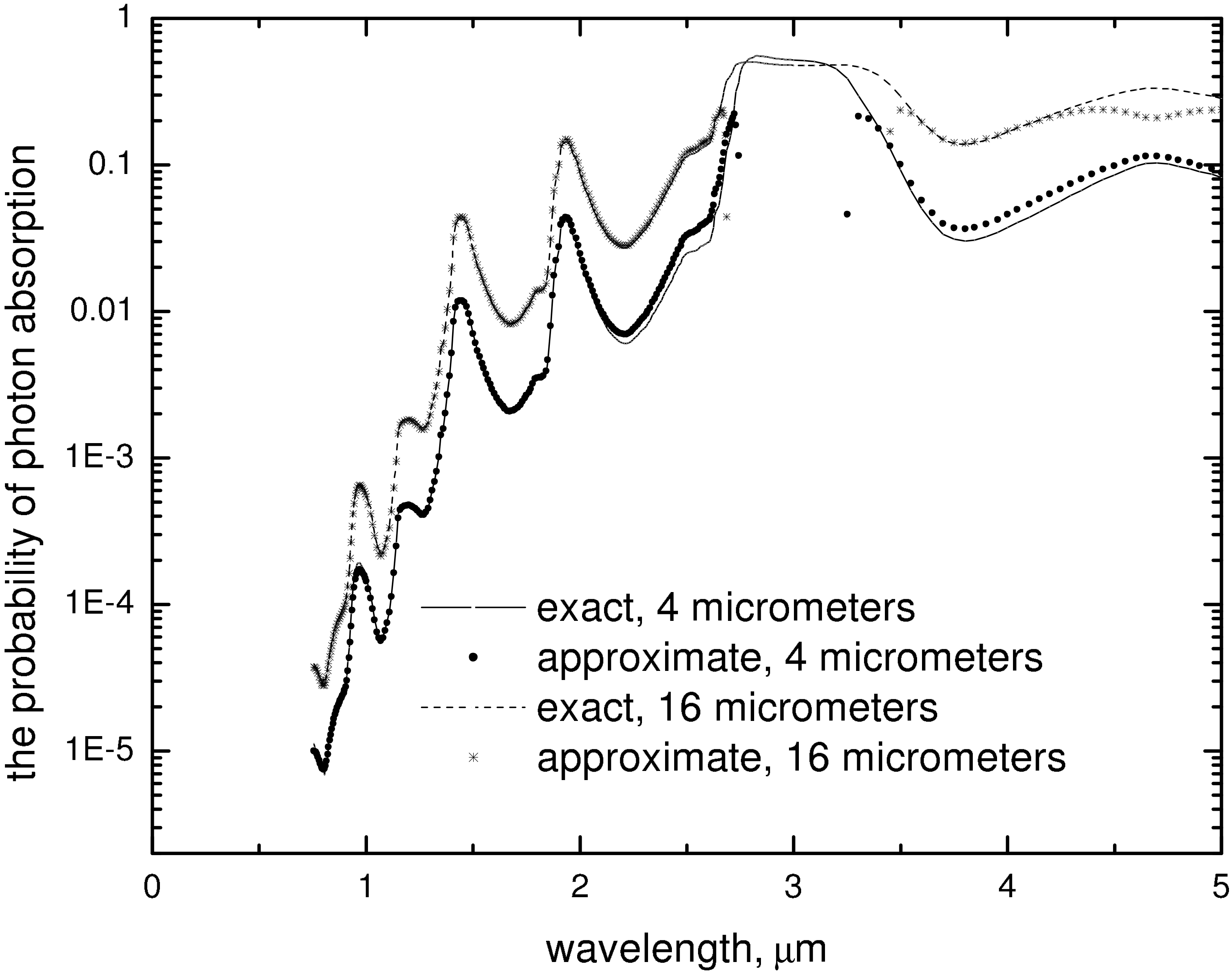

water
ice
real part of the refractive index
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0
1
2
3
4
5
wavelength, μm



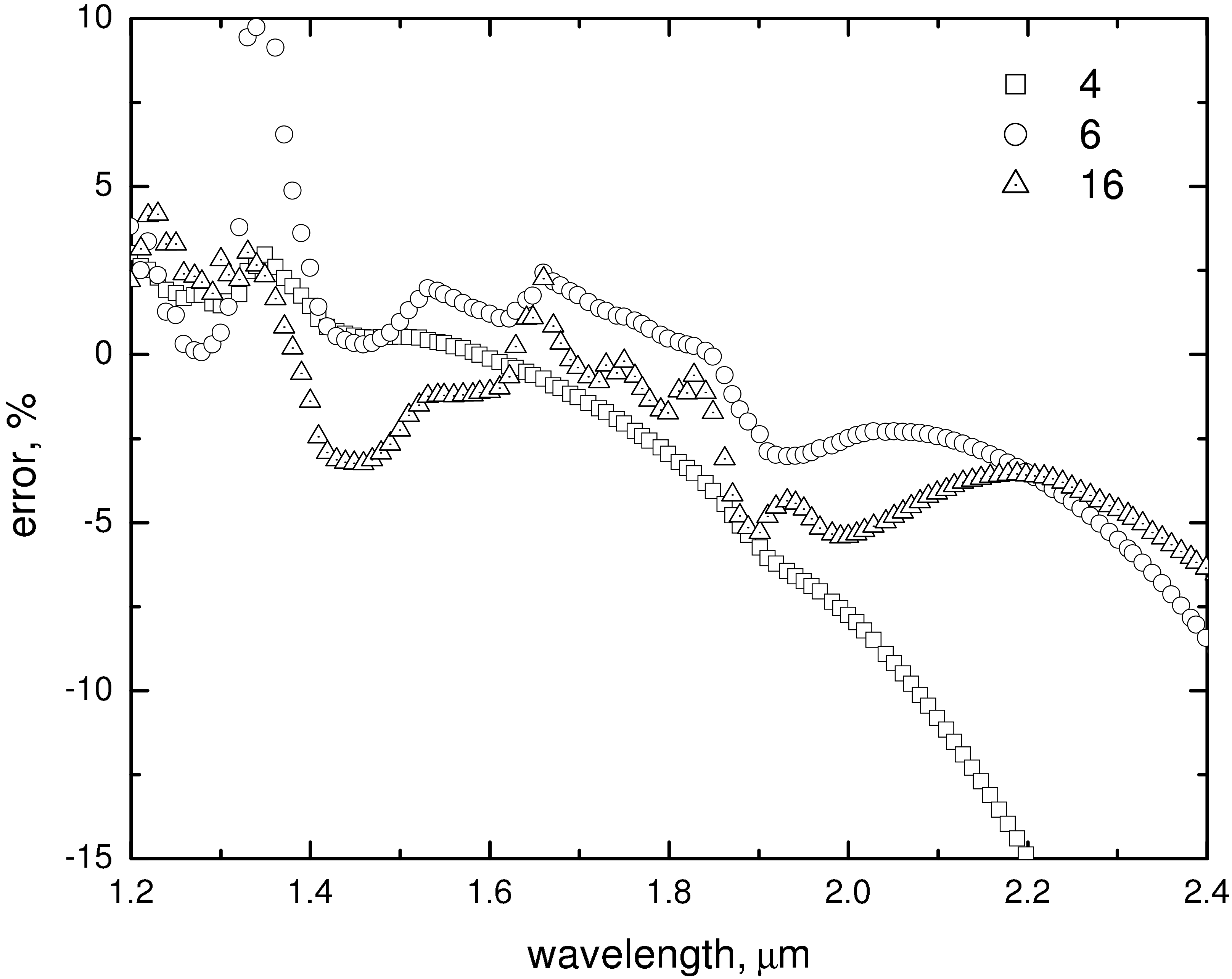
Mie theory
approximation
0.60
0.55
0.50
0.45
0.40
0.35
0
1
2
3
4
5
σext, m-1
λ,μm



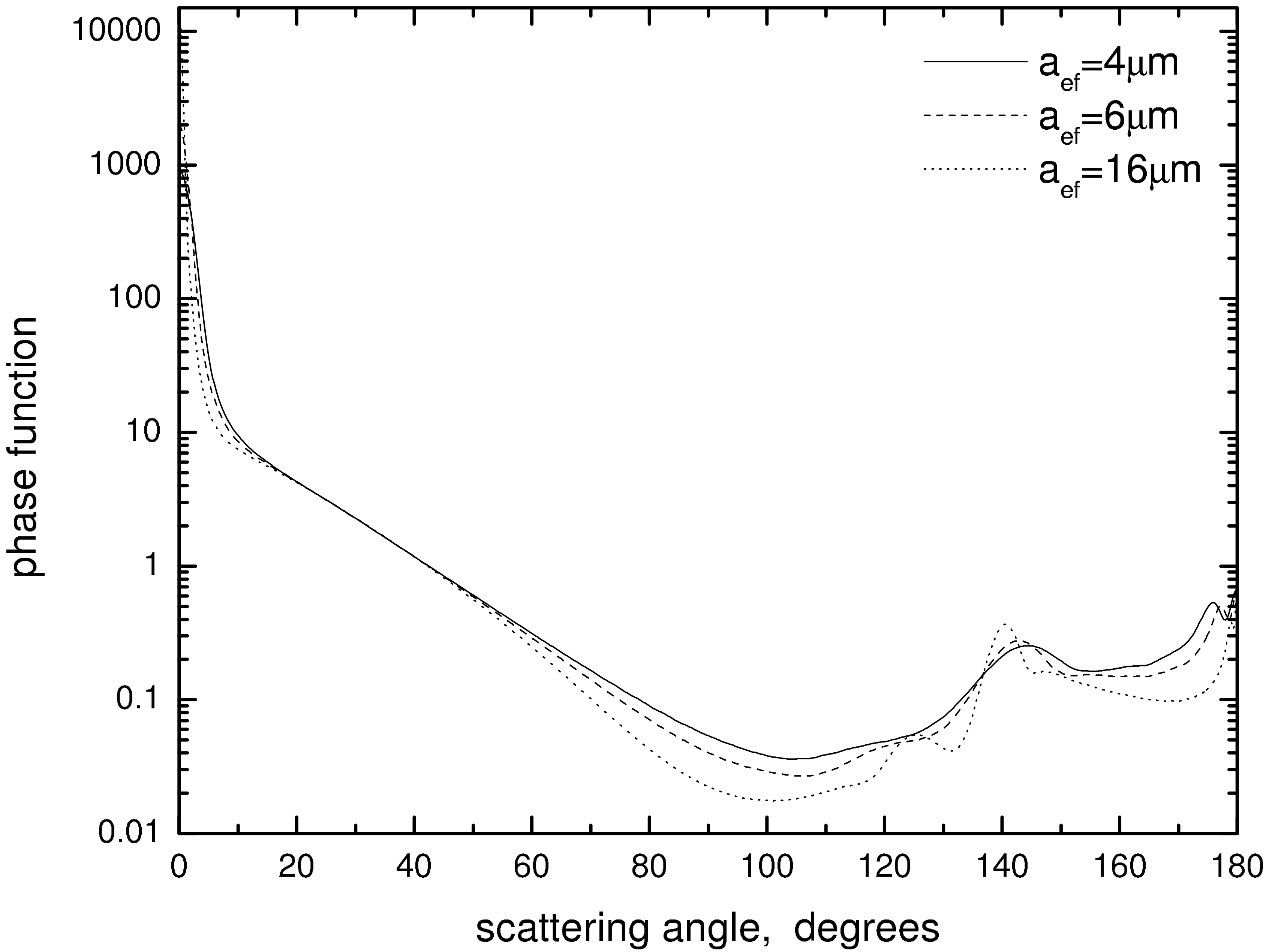
2.0
1.9
1.8
1.7
1.6
1.5
B
1.2
1.3
1.4
1.5
1.6
1.7
1.8
λ,μm

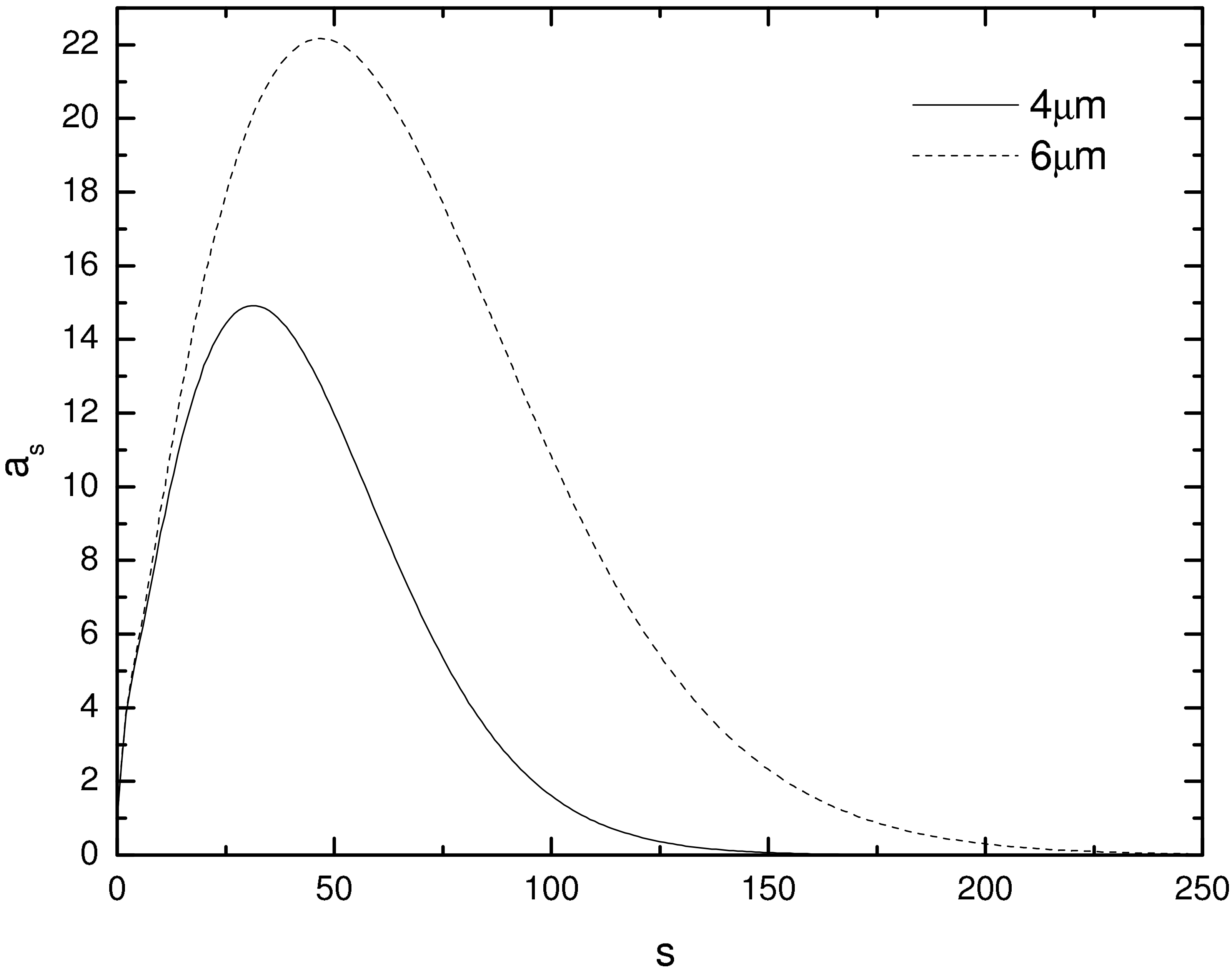


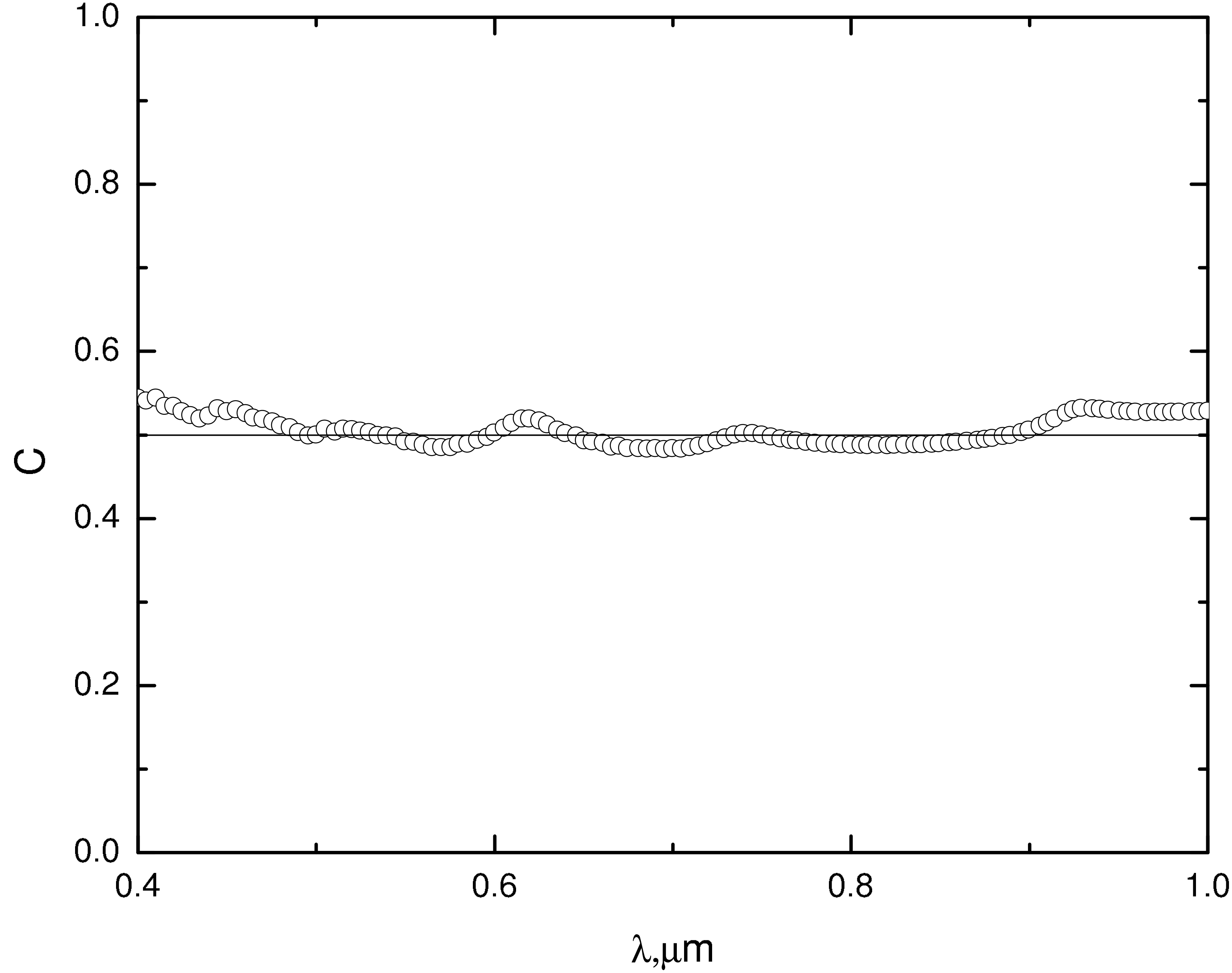
1
0.1
0.01
1E-3
1E-4
1E-5
0
1
2
3
4
5
the probability of photon absorption
wavelength, μm
exact, 4 micrometers
approximate, 4 micrometers
exact, 16 micrometers
approximate, 16 micrometers

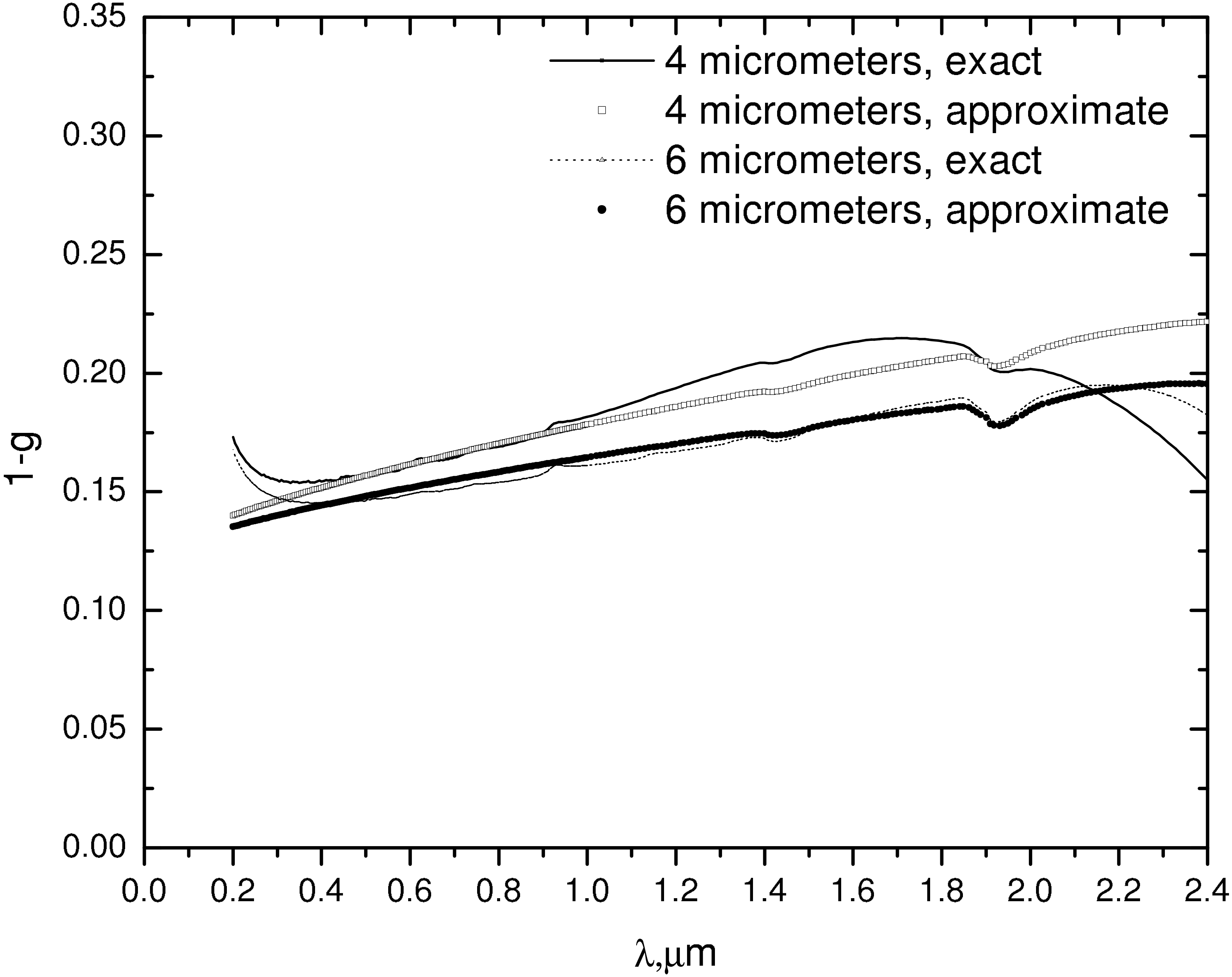


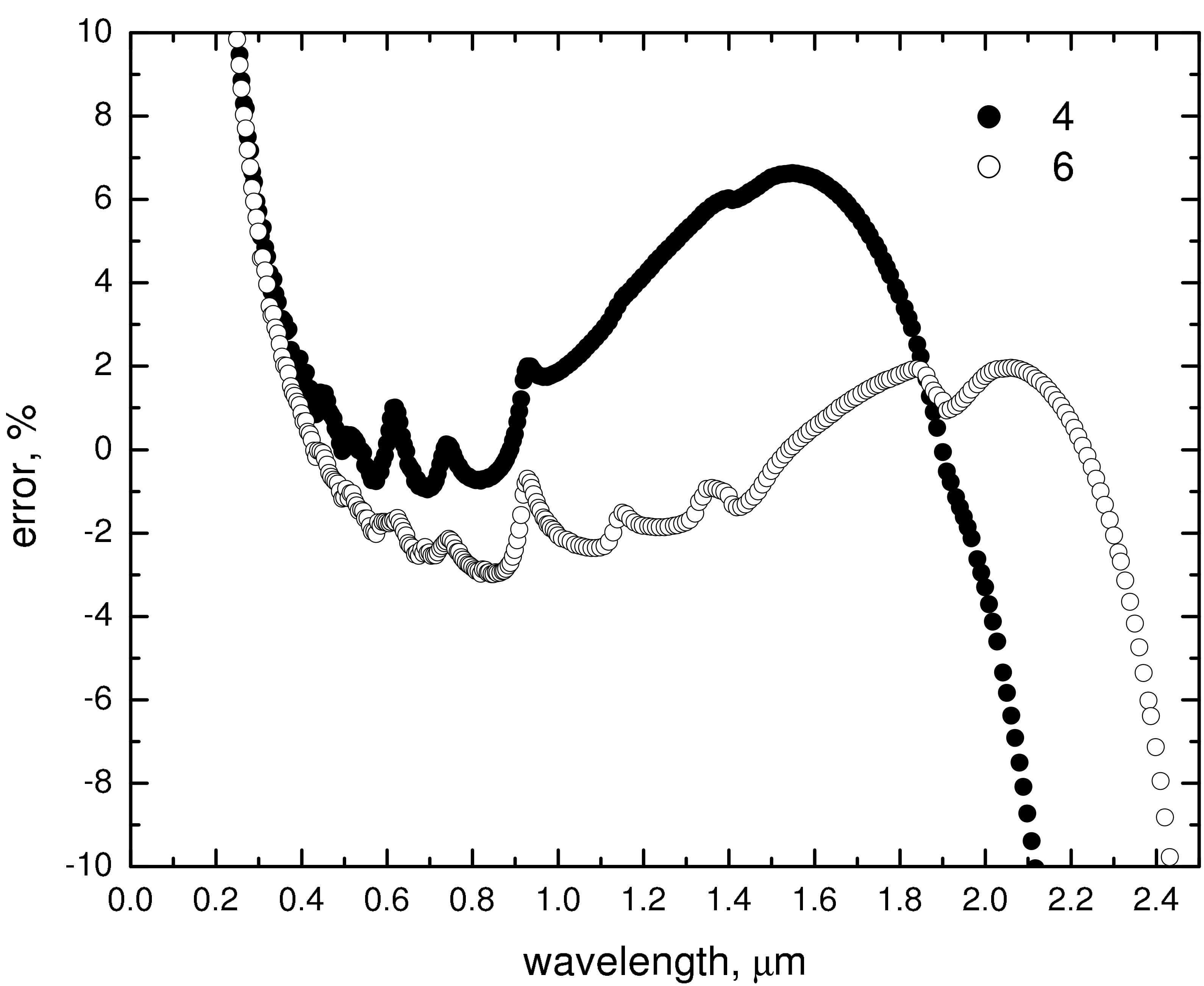
10
5
0
-5
-10
-15
error, %
1.2
1.4
1.6
1.8
2.0
2.2
2.4
wavelength, μm
4
6
16


phase function
scattering angle, degrees
a_ef=4μm
a_ef=6μm
a_ef=16μm
10000
1000
100
10
1
0.1
0.01
0
20
40
60
80
100
120
140
160
180

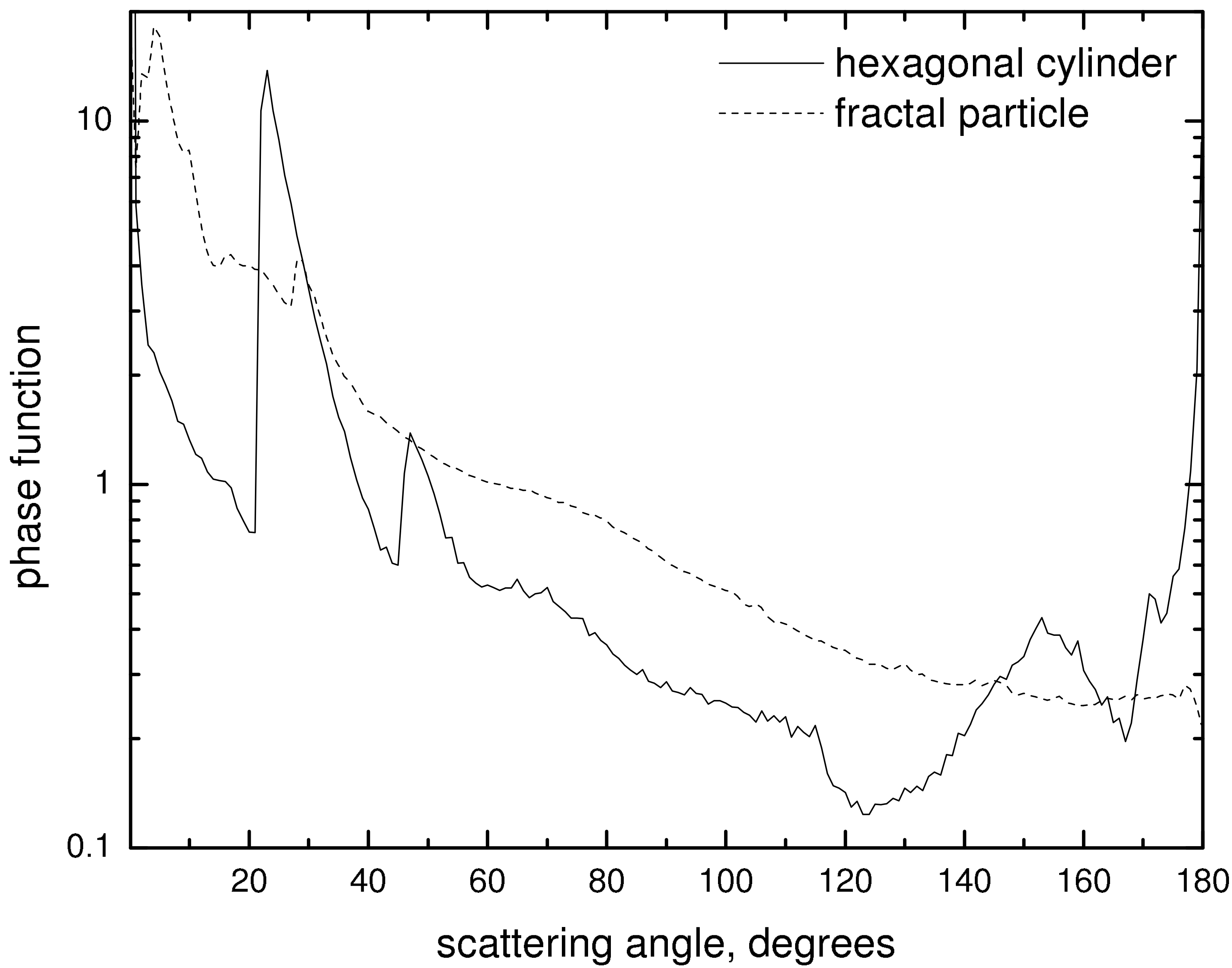

4μm
6μm
0
50
100
150
200
250
s
0
2
4
6
8
10
12
14
16
18
20
22
a_s

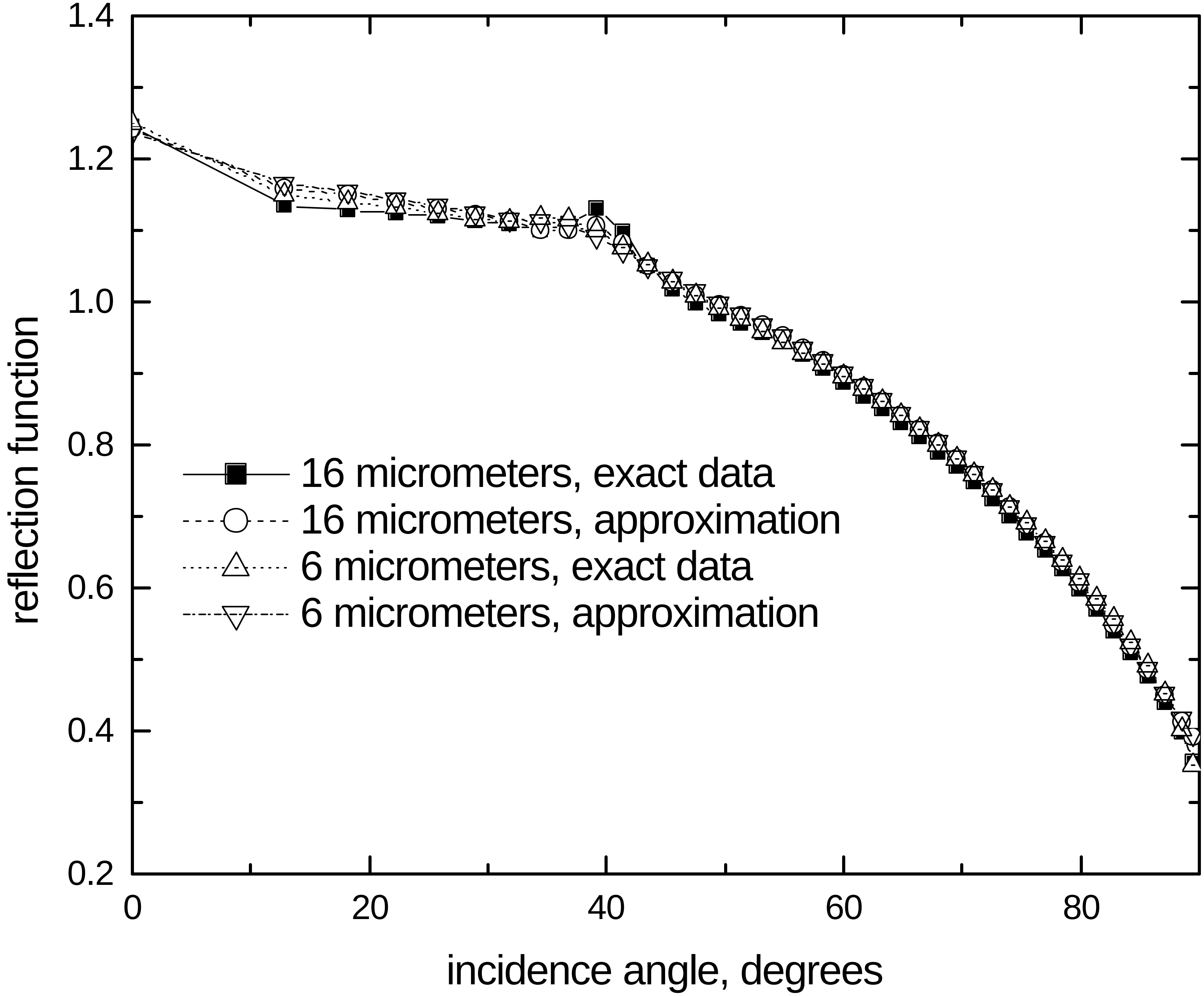

1.0
0.8
0.6
0.4
0.2
0.0
C
0.4
0.6
0.8
1.0
λ,μm

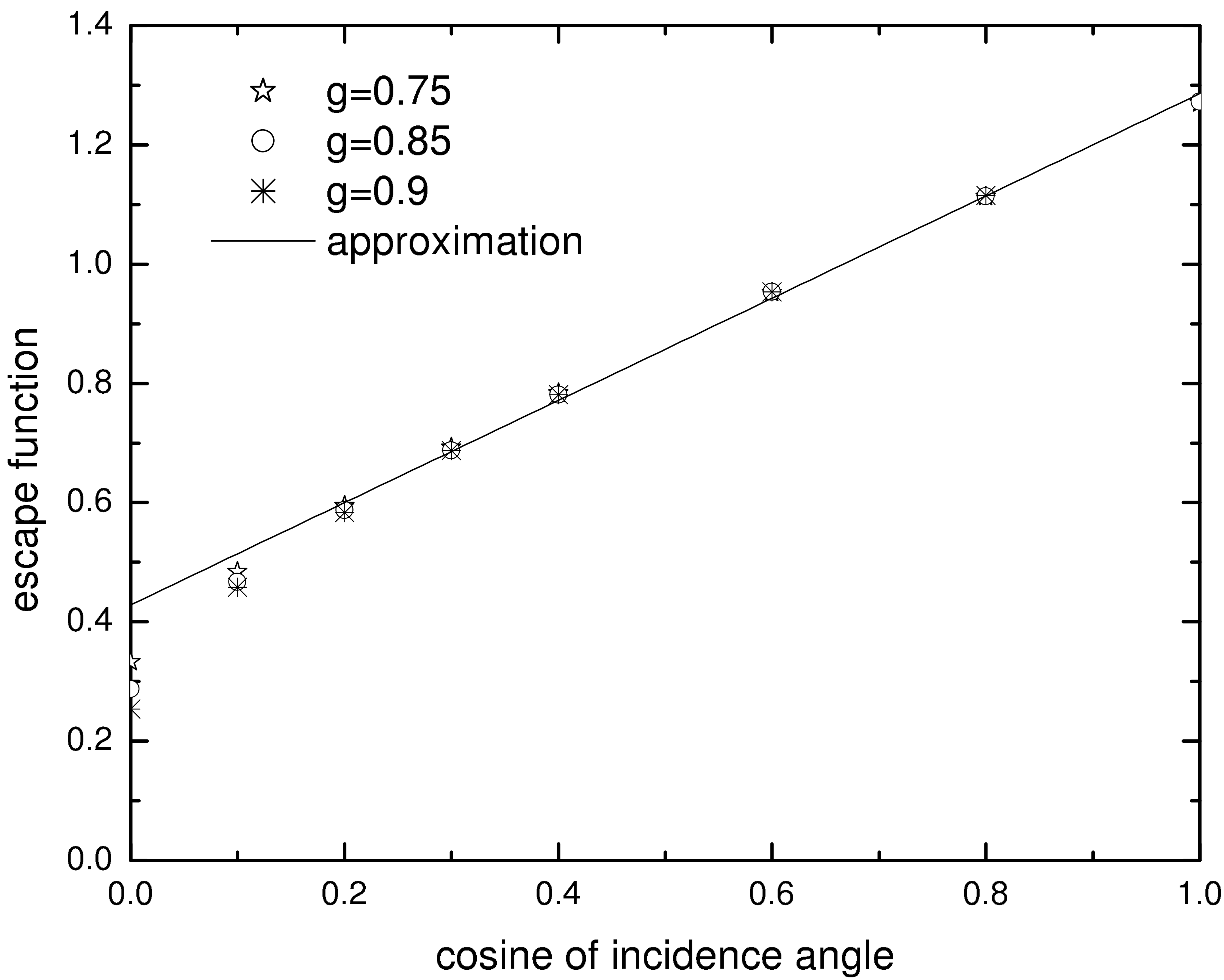

4 micrometers, exact
4 micrometers, approximate
6 micrometers, exact
6 micrometers, approximate
1-g
λ,μm
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4

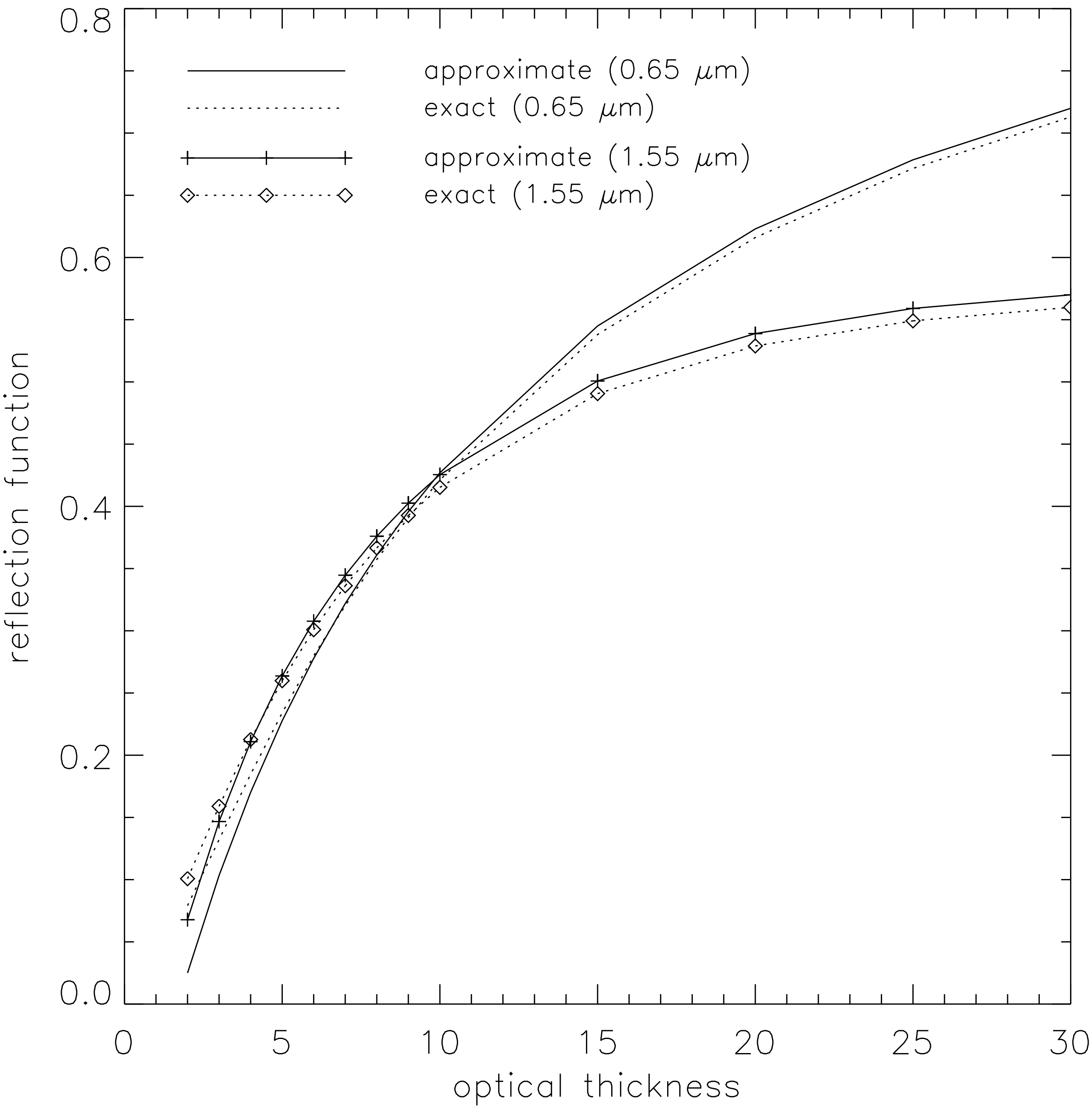


10
8
6
4
2
0
-2
-4
-6
-8
-10
error, %
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
wavelength, μm
4
6

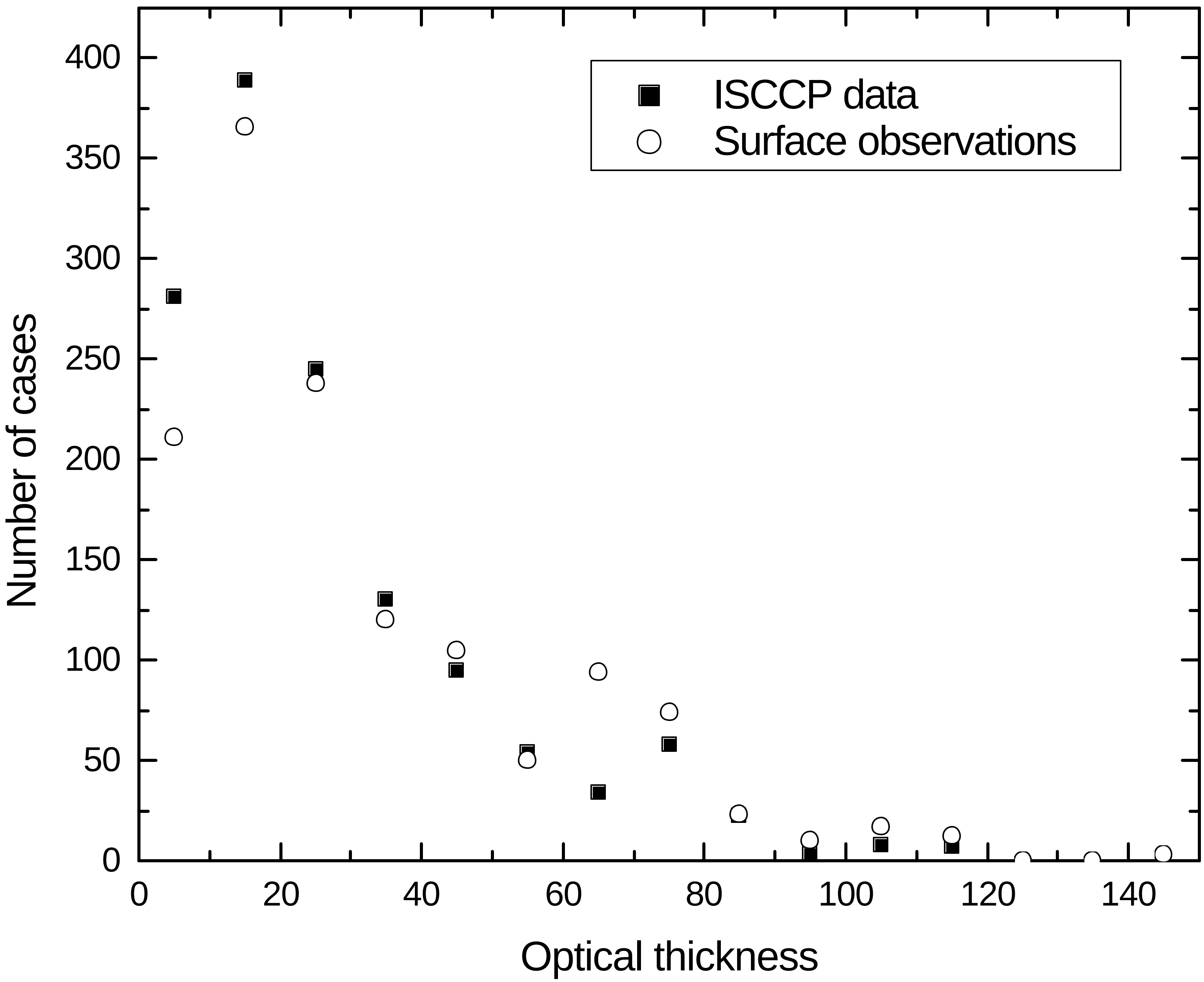

hexagonal cylinder
fractal particle
phase function
10
1
0.1
20
40
60
80
100
120
140
160
180
scattering angle, degrees


1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
20
40
60
80
reflection function
incidence angle, degrees
16 micrometers, exact data
16 micrometers, approximation
6 micrometers, exact data
6 micrometers, approximation

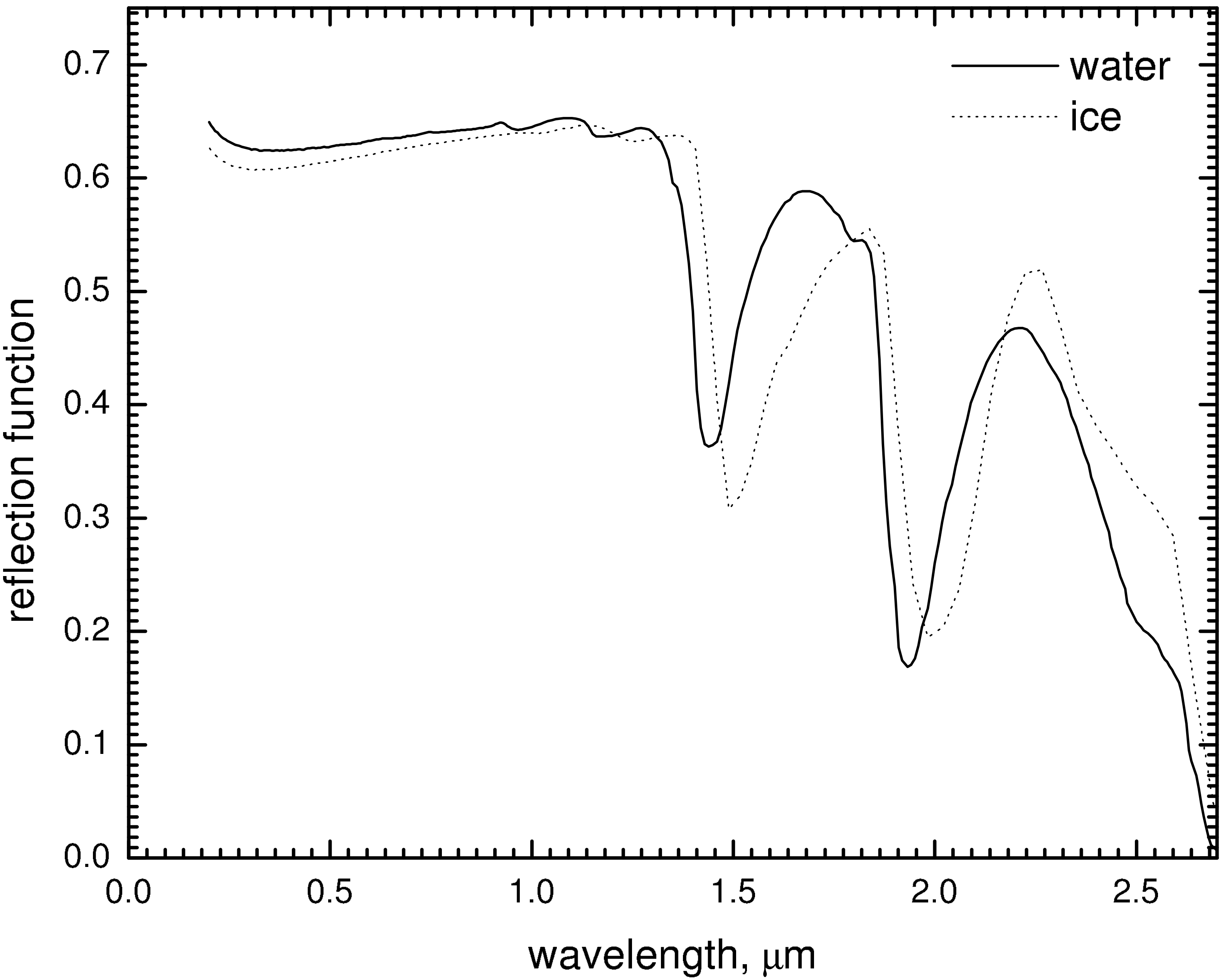

g=0.75
g=0.85
g=0.9
approximation
escape function
cosine of incidence angle
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4



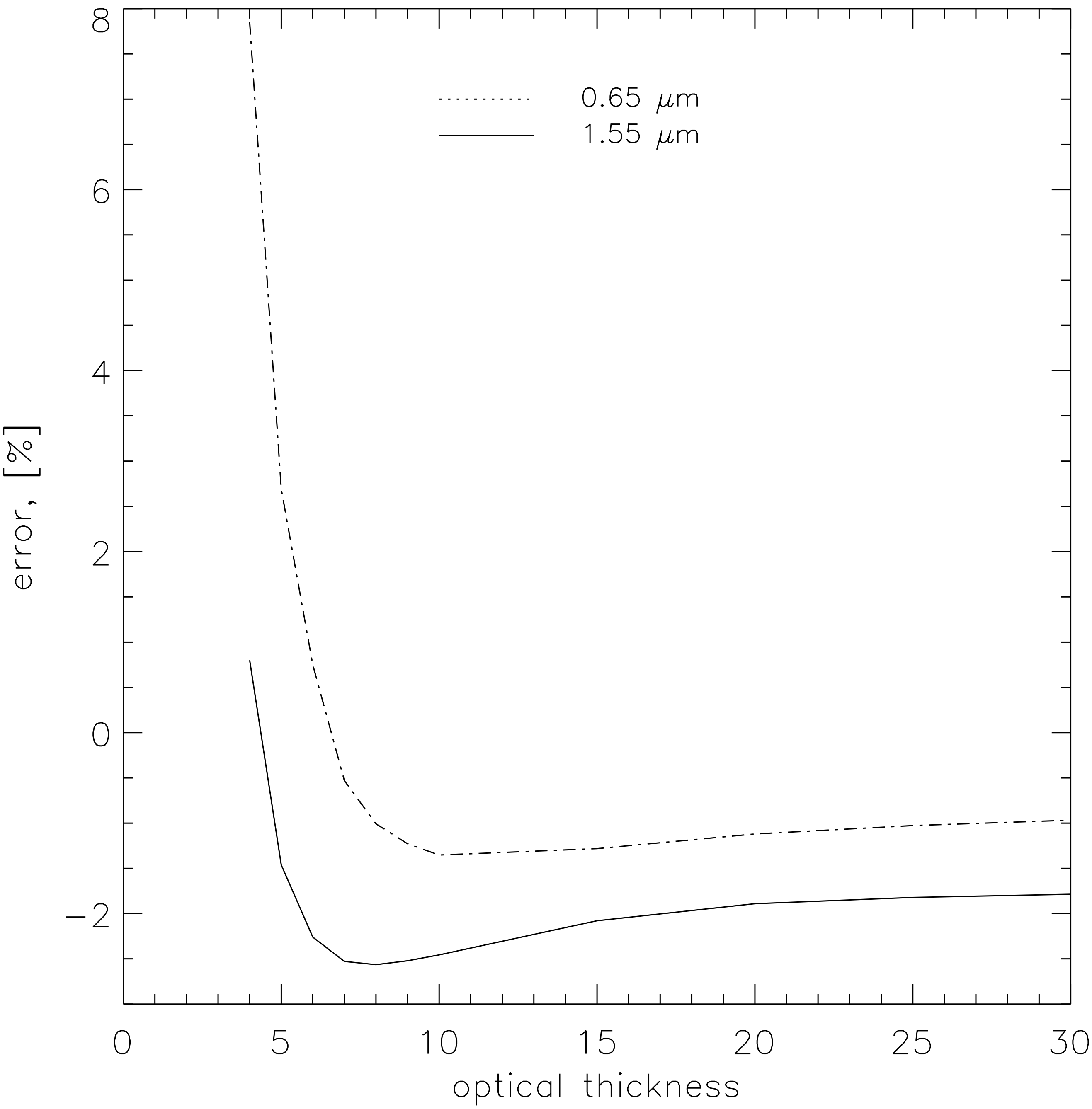
approximate (0.65 μm)
exact (0.65 μm)
approximate (1.55 μm)
exact (1.55 μm)
reflection function
optical thickness
0.0
0.2
0.4
0.6
0.8
0
5
10
15
20
25
30



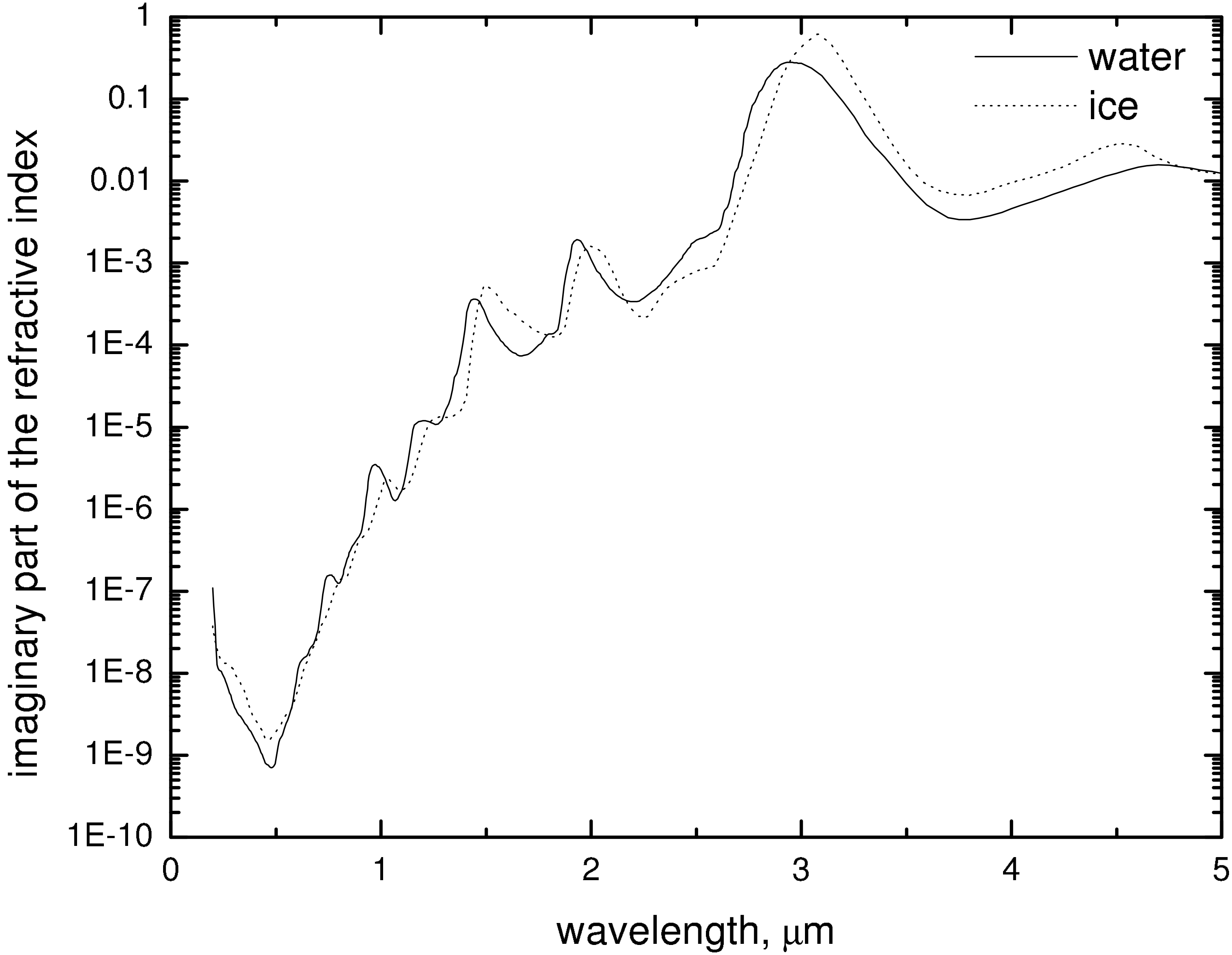
ISCCP data
Surface observations
Number of cases
Optical thickness
0
50
100
150
200
250
300
350
400
0
20
40
60
80
100
120
140



water
ice
reflection function
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.0
0.5
1.0
1.5
2.0
2.5
wavelength, μm



0.65 μm
1.55 μm
error, [%]
optical thickness
8
6
4
2
0
−2
0
5
10
15
20
25
30


water
ice
imaginary part of the refractive index
1
0.1
0.01
1E-3
1E-4
1E-5
1E-6
1E-7
1E-8
1E-9
1E-10
0
1
2
3
4
5
wavelength, μm

spherical particles with the effective radius 6 μm. It is assumed that particles in a cloud are characterized by the gamma particle size distribution (2.3) with the parameter $\mu = 6$. The geometrical thickness of cloud is equal to 500m. The liquid water path equal to $100g/m^2$, which gives the optical thickness equal to 27 at the wavelength 0.55 μm. Computations of local optical characteristics were performed, using Eqs. (3.11), (3.23), (3.37). The reflection of light from surface, scattering and absorption of light by aerosols and gases are neglected.