Cloud Top Pressure and A Fast Radiative Transfer Model for Simulating O2 B-band

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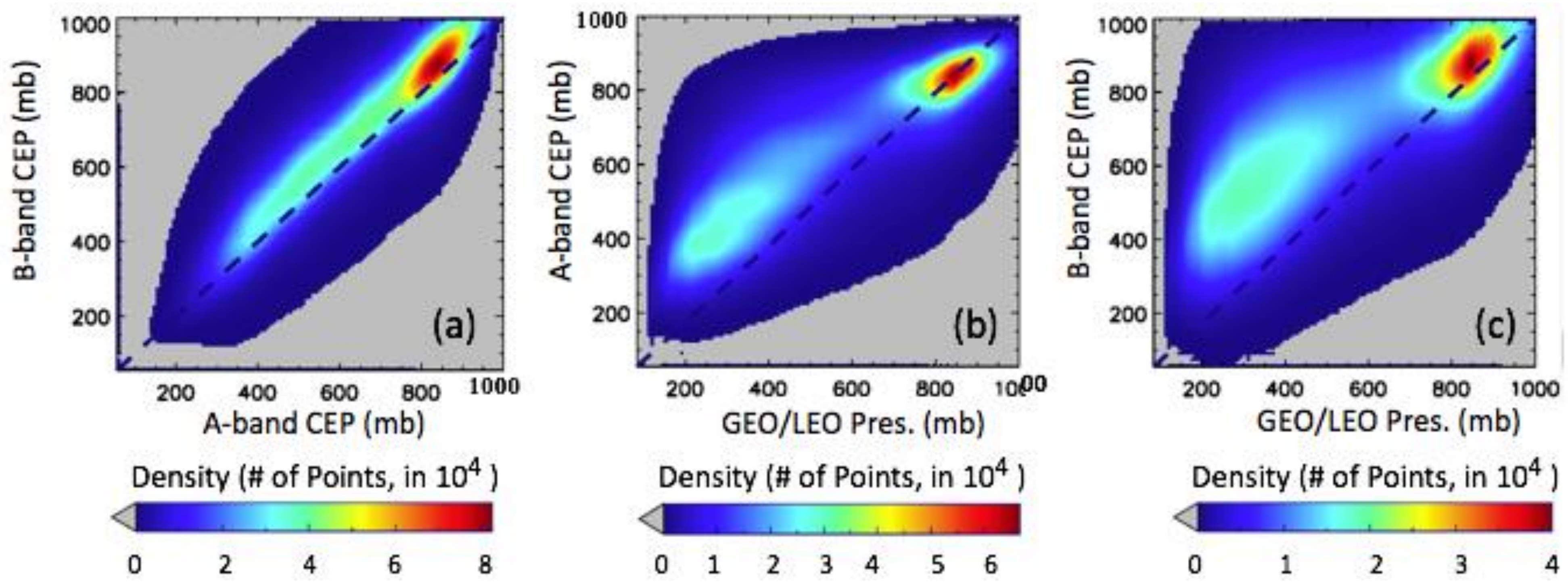
EPIC L2 Cloud Product List

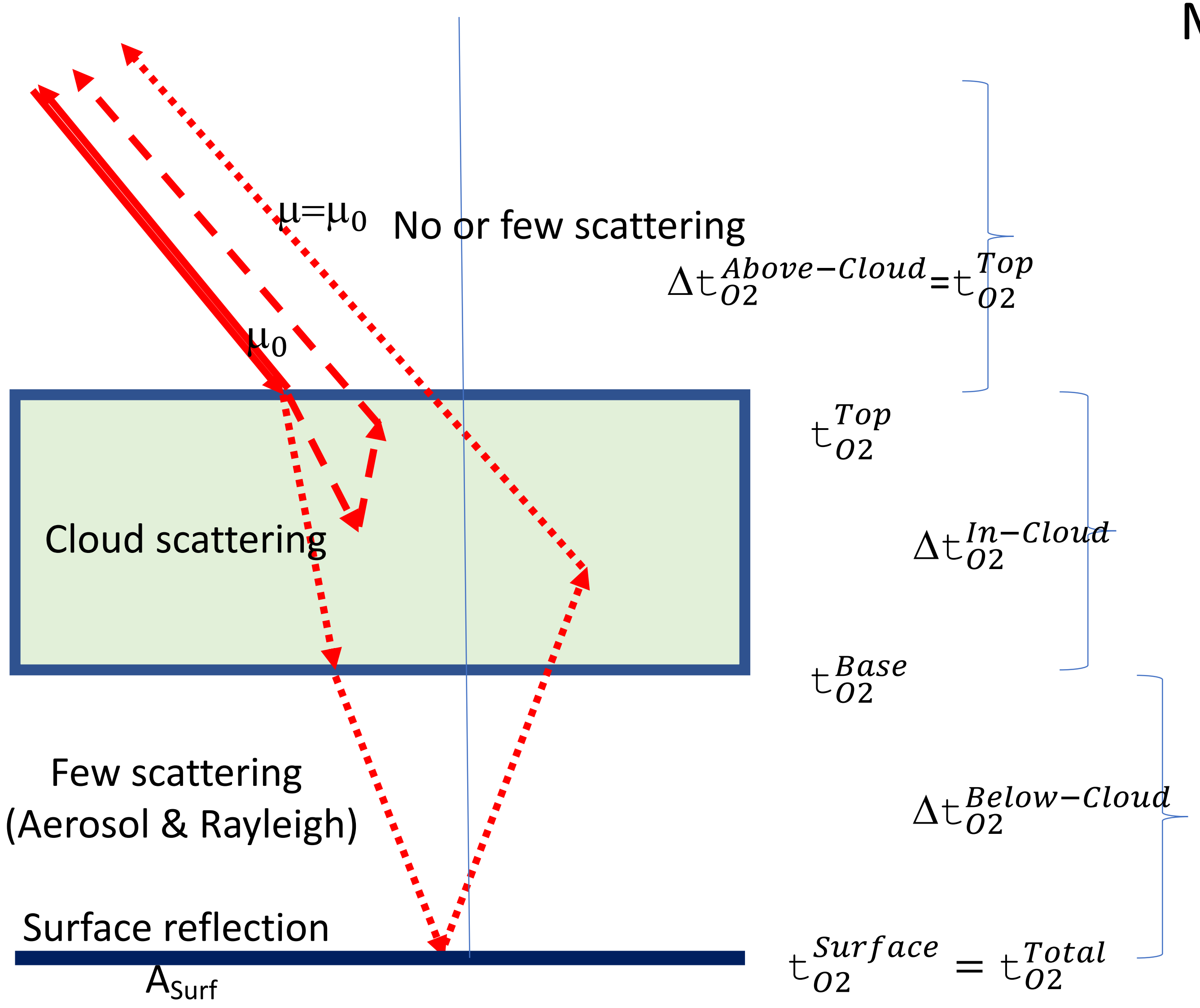
1) EPIC Cloud Mask
2) Oxygen A-band Cloud Effective Pressure
3) Oxygen A-band Cloud Effective Height
4) Oxygen B-band Cloud Effective Pressure
5) Oxygen B-band Cloud Effective Height
6) Cloud Optical Thickness – assuming liquid phase
7) Cloud Optical Thickness – assuming ice phase
8) Cloud Effective Temperature
9) Most likely cloud thermodynamic phase

EPIC vs GEO/LEO composites: Effective Cloud Pressure

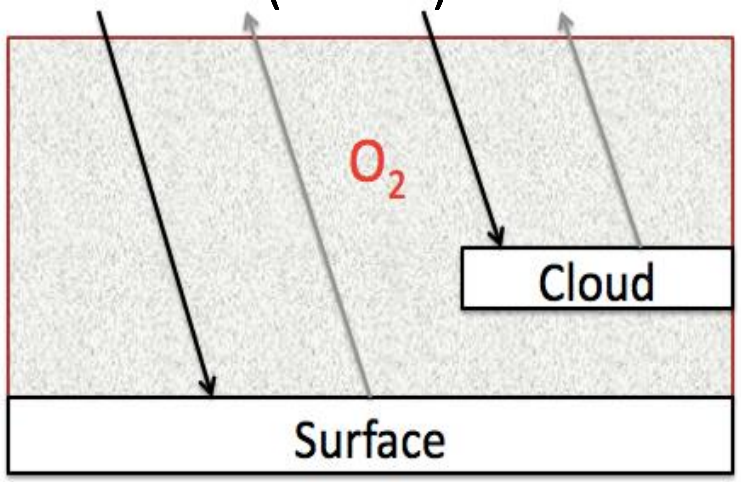


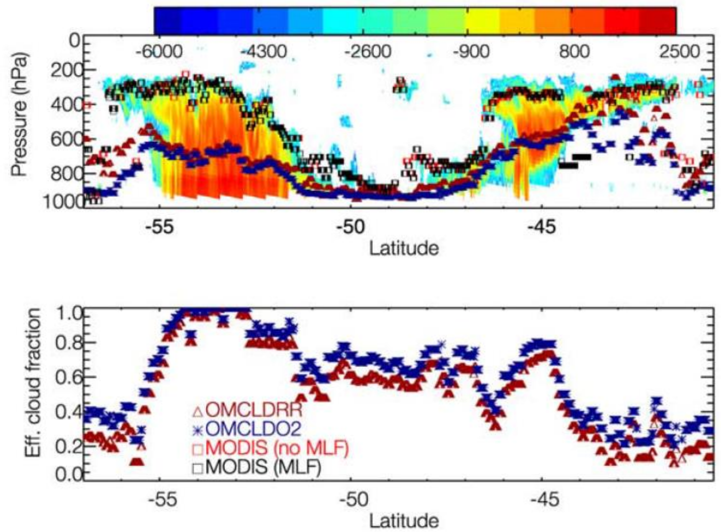
Effective cloud pressure are generally higher (lower altitude) than the physical cloud top; factors contribute to the A- and B-band differences include penetration depths differences, surface albedo differences, geolocation uncertainties, cloud evolution etc.

Cloud Top Pressure vs. Cloud Effective Pressure



Mixed Lambertian Equivalent Reflectivity (MLER)





Radiative Transfer and Photon Path Length Distribution

Equivalence theorem: to separate absorption from scattering

$$I_\nu(\mu,\phi;\mu_0,\phi_0) = I_0(\mu,\phi;\mu_0,\phi_0)\int_0^\infty p(l,\mu,\phi;\mu_0,\phi_0)e^{-\kappa_\nu l}dl$$

Where *p(l)* is photon path length distribution with path length *l*

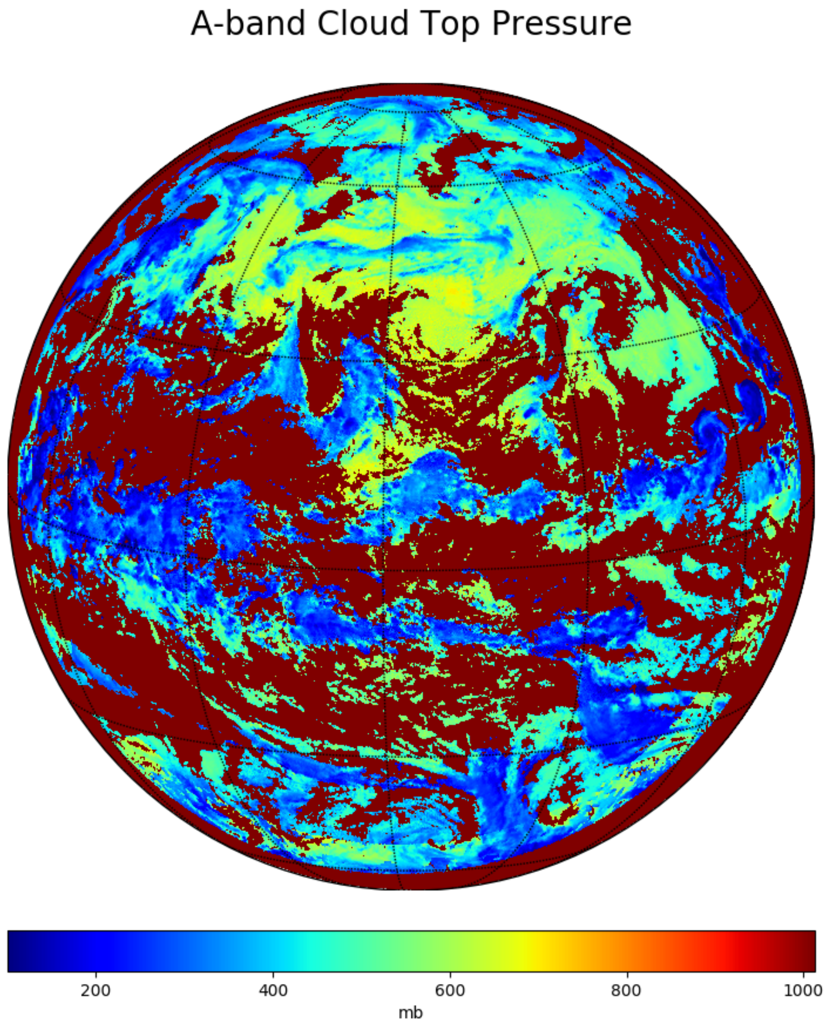
K_ν is gaseous absorption coefficient

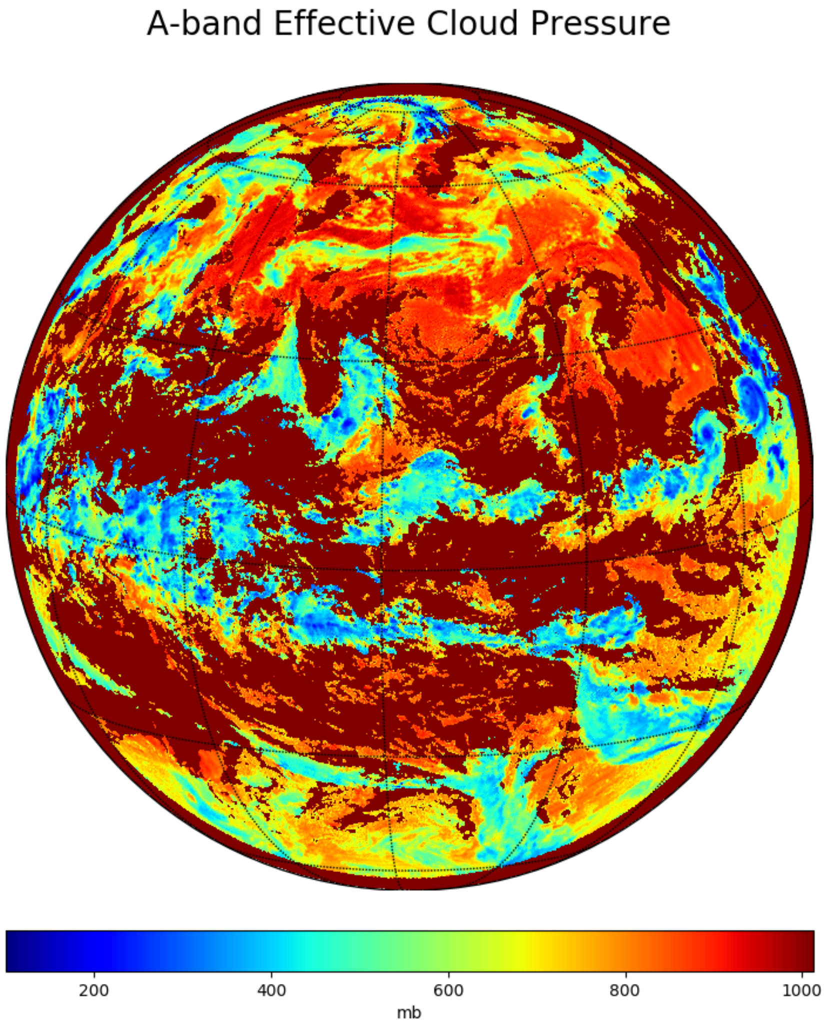
The analytical EPIC model:

$$-\log\left(\frac{R_A}{R_f}\right) = \frac{2}{\mu_0}\tau_{O2}^{Top}$$
$$+\left(a1\sqrt{\tau_{O2}^{Top}} + b1(\tau_{O2}^{Top})\right)(a2*T+b2*(\mu+\mu_0)+c2*T*(\mu+\mu_0)+d2\mu\ \ \mu_0)$$
$$+\ \Delta\tau_{O2}^{In-Cloud}T(a3*T+b3\ (\mu+\mu_0)+c3*T*(\mu+\mu_0)+d3\mu\ \ \mu_0)$$
$$+\ \Delta\tau_{O2}^{Below-Cloud}\frac{A_{Surf}}{1+(e4*T+f4)*A_{Surf}}T(a4*T+b4\ (\mu+\mu_0)+c4*T*(\mu+\mu_0)+d4\mu\ \ \mu_0)$$

The coefficients are determined through nonlinear regression.

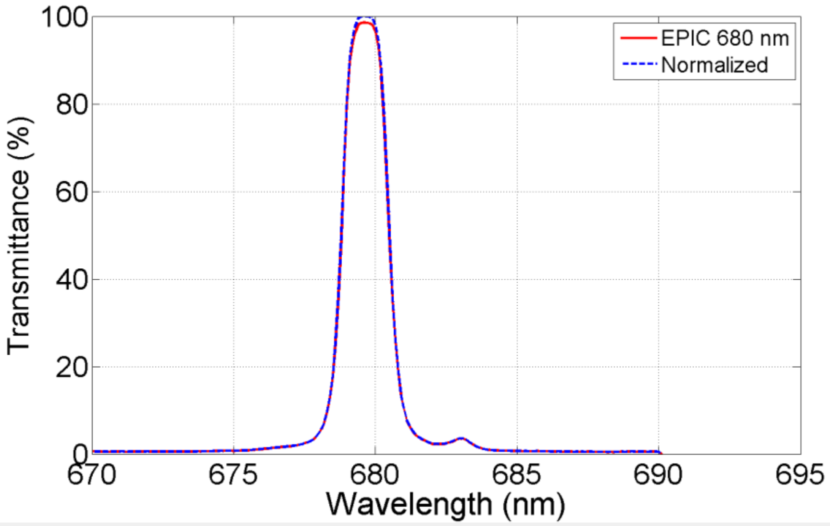
On Cloud Top Pressure: epic_1b_20160725001751_01.h5



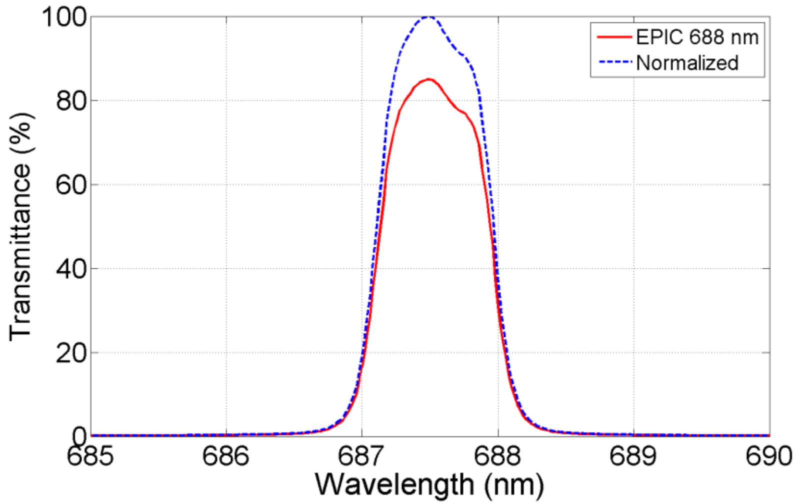


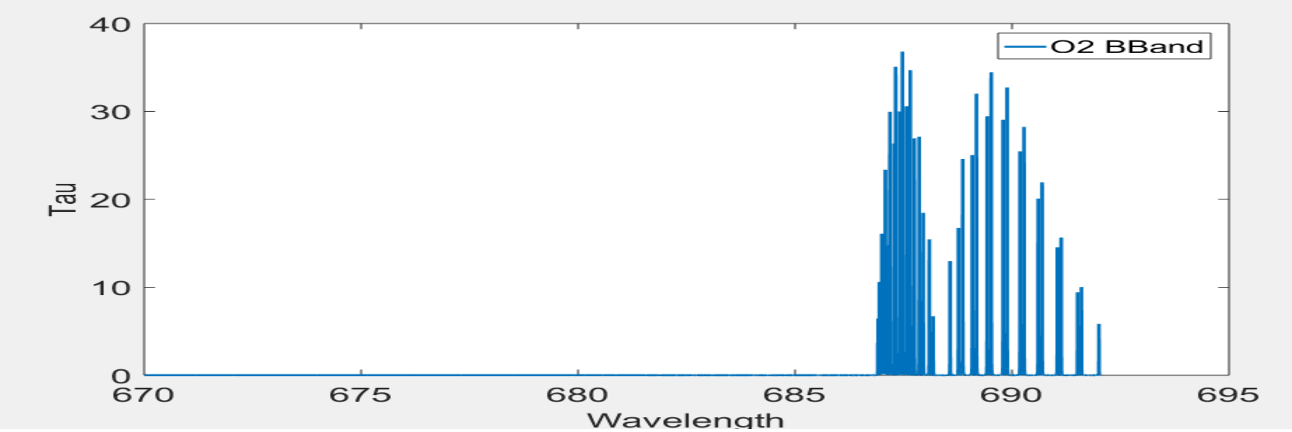
EPIC O2 B Band Filter function

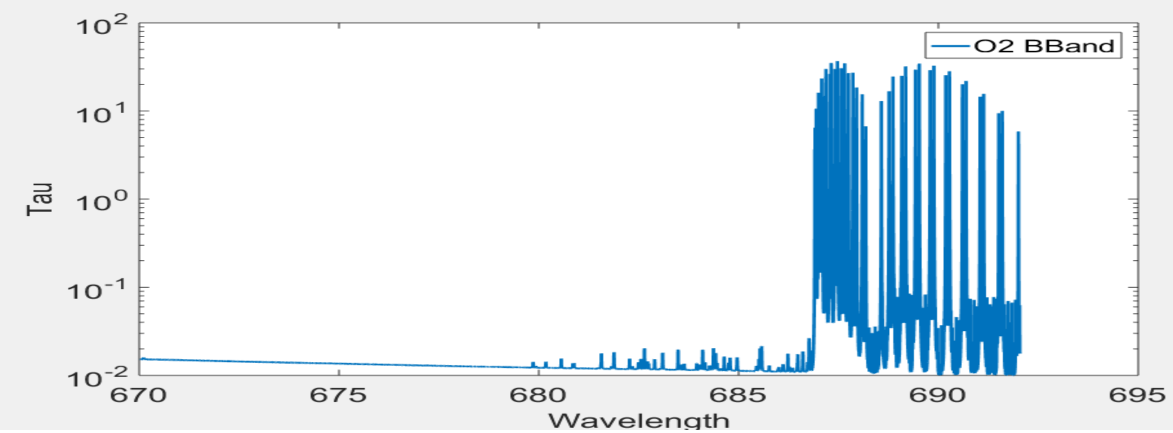
FWHM: 678.80nm~680.48   Central: 679.64 nm



FWHM: 687.11nm~687.97   Central: 687.54 nm







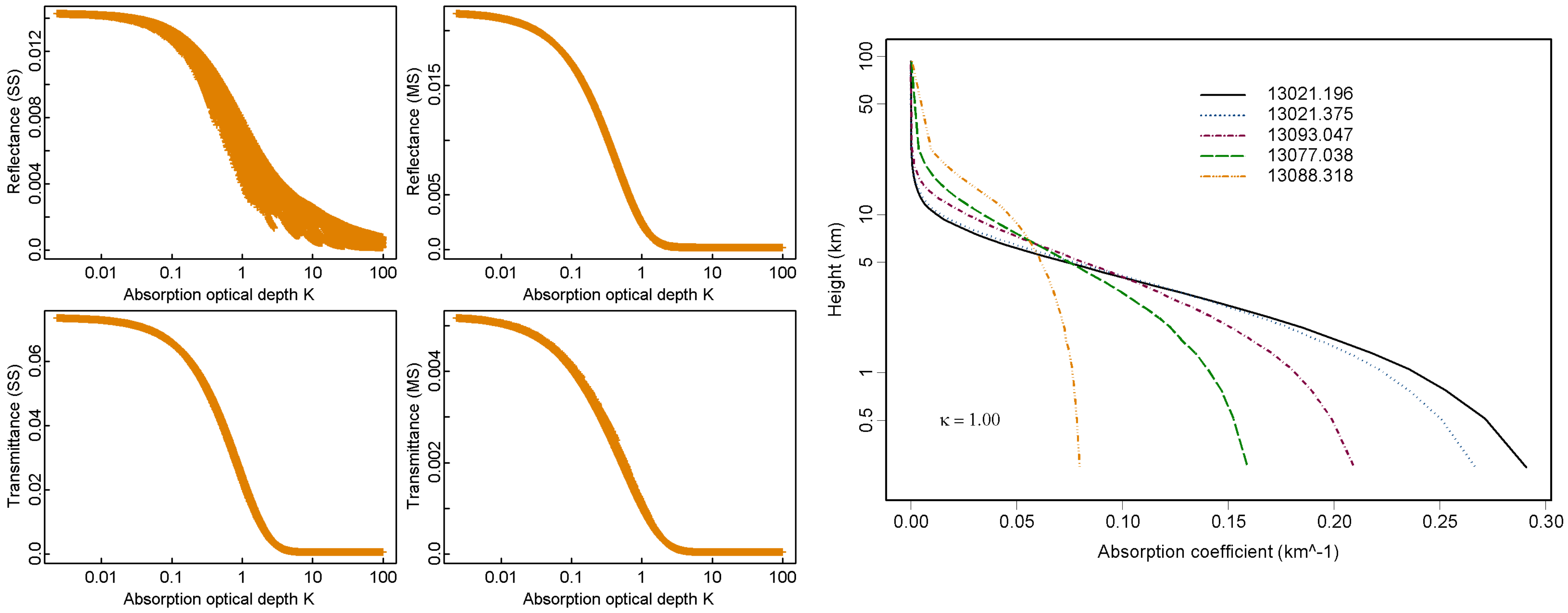
A forward RT model: accuracy vs. speed

$$\mathrm{R}(\lambda) = \int S(k(\lambda))R(k(\lambda))d\lambda \neq R(\overline{k(\lambda))}$$

A fast radiative transfer model [Min and Harrison 2004; Duan et al, 2005]:

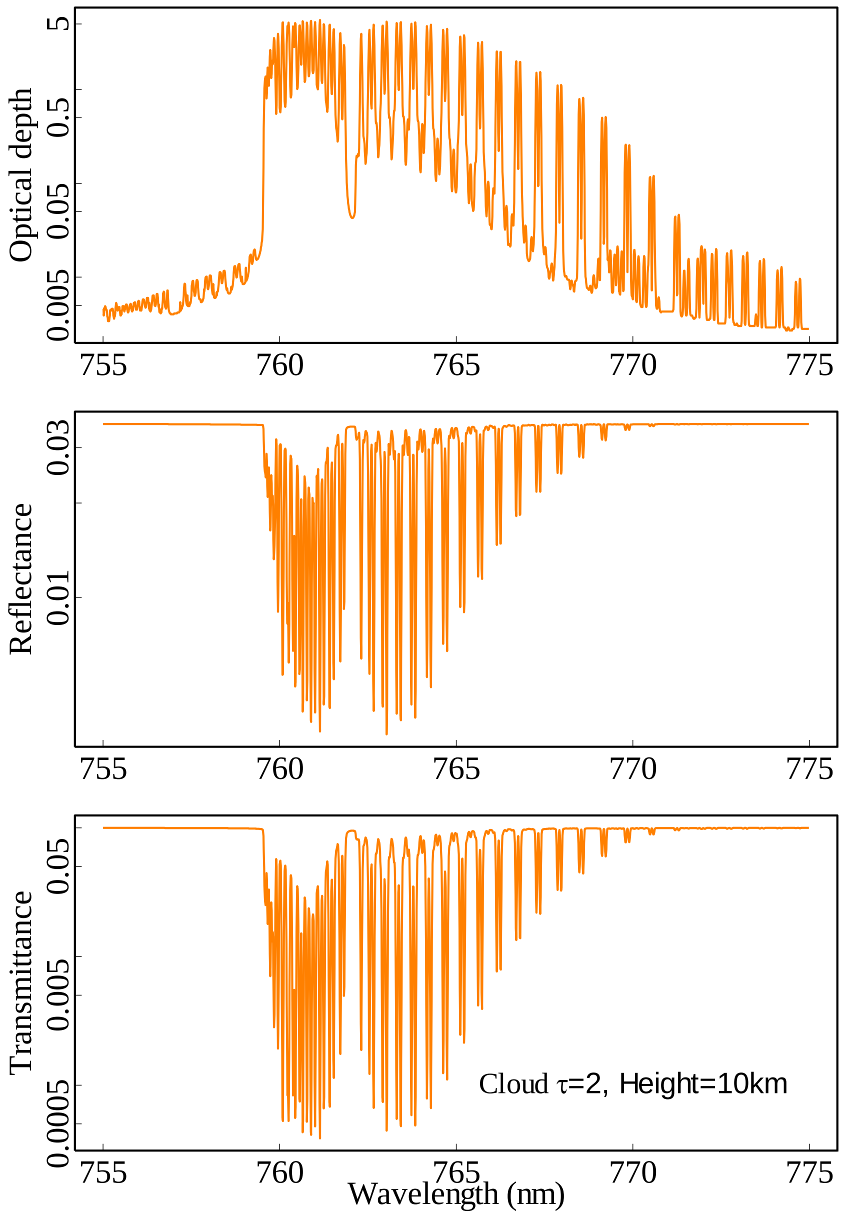
$$\begin{aligned}
I &= I^{ss}(\lambda) + I^{ms}(\lambda) \\
&\approx I^{ss}[Z^h(p,t), P^h, \lambda] + I^{ms}[Z^h(p,t), P^h, \lambda] \\
&\approx I^{ss}[Z^h(p,t), P^h, \lambda] + I^{ms}[Z^l(p,t), P^l, \lambda] \\
&\approx I^{ss}[Z^h(p,t), P^h, \lambda] + I^{ms}\{F[Z^l(p,t), P^l, k(\lambda_i)]\}
\end{aligned}$$

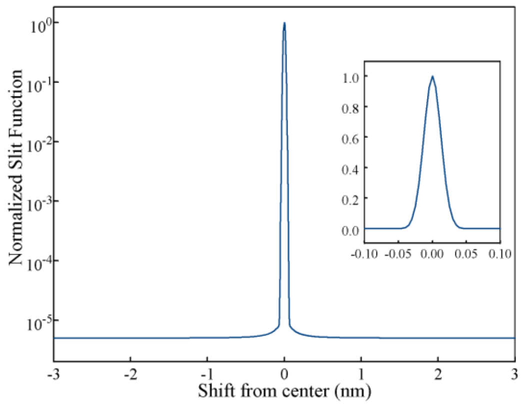
A fast RT model: k vs. double k

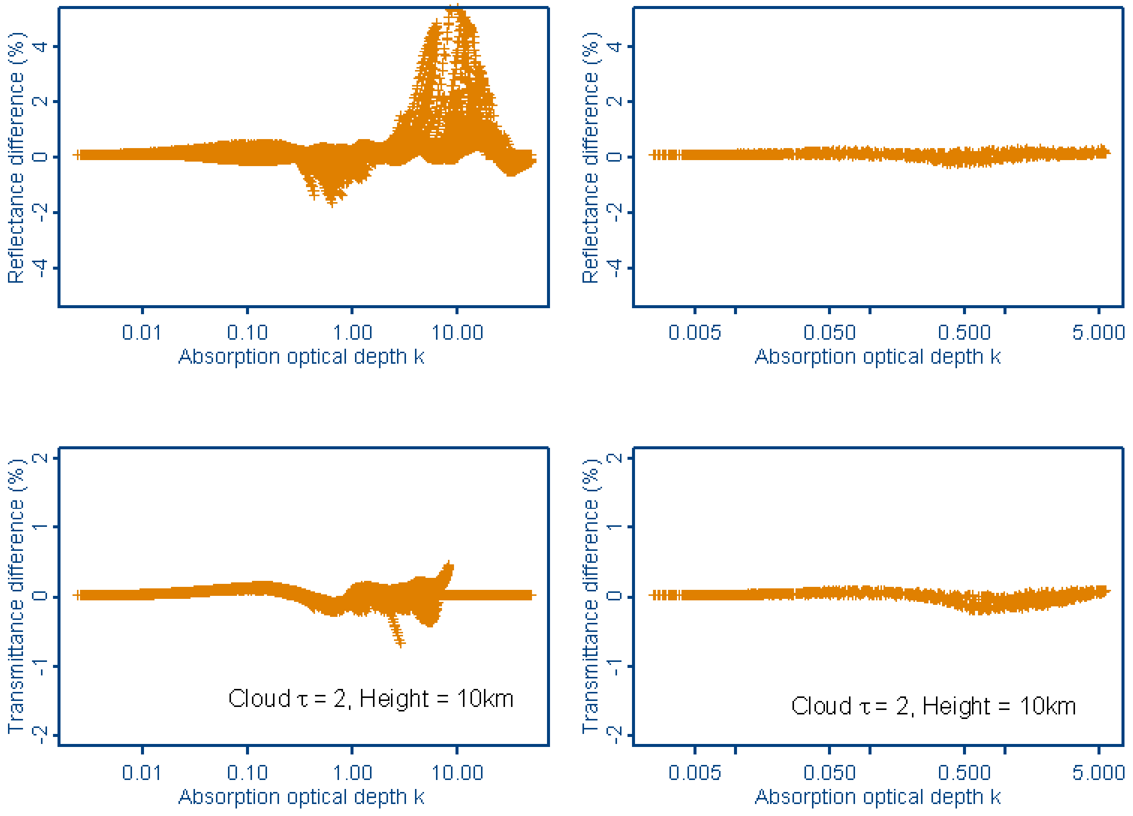


$$I^{ms}(\lambda) = I^{ms}\{F[Z^l(p,t), P^l, k(\lambda_i)]\} = I^{ms}\{F[k'(\lambda), k(\lambda)]\} = g(k)\, f_k(k'/k)$$

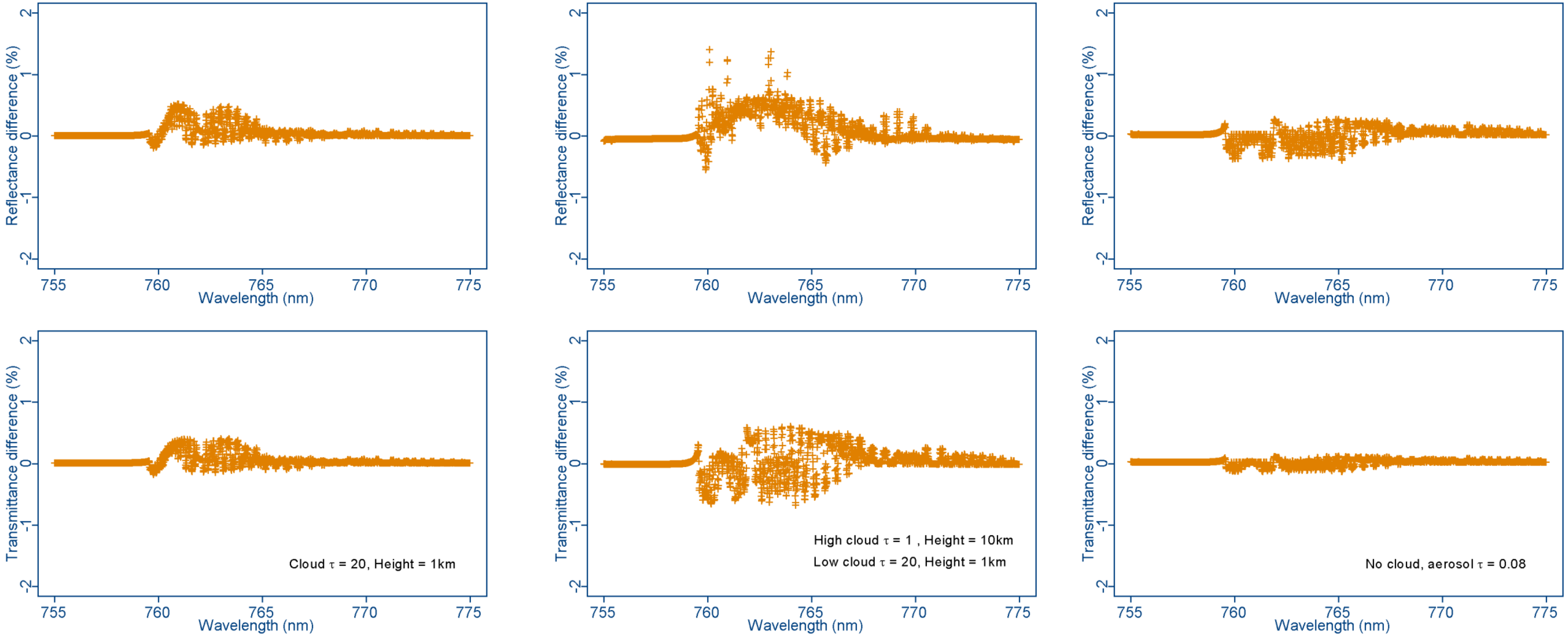
A fast RT model: results (A-band)



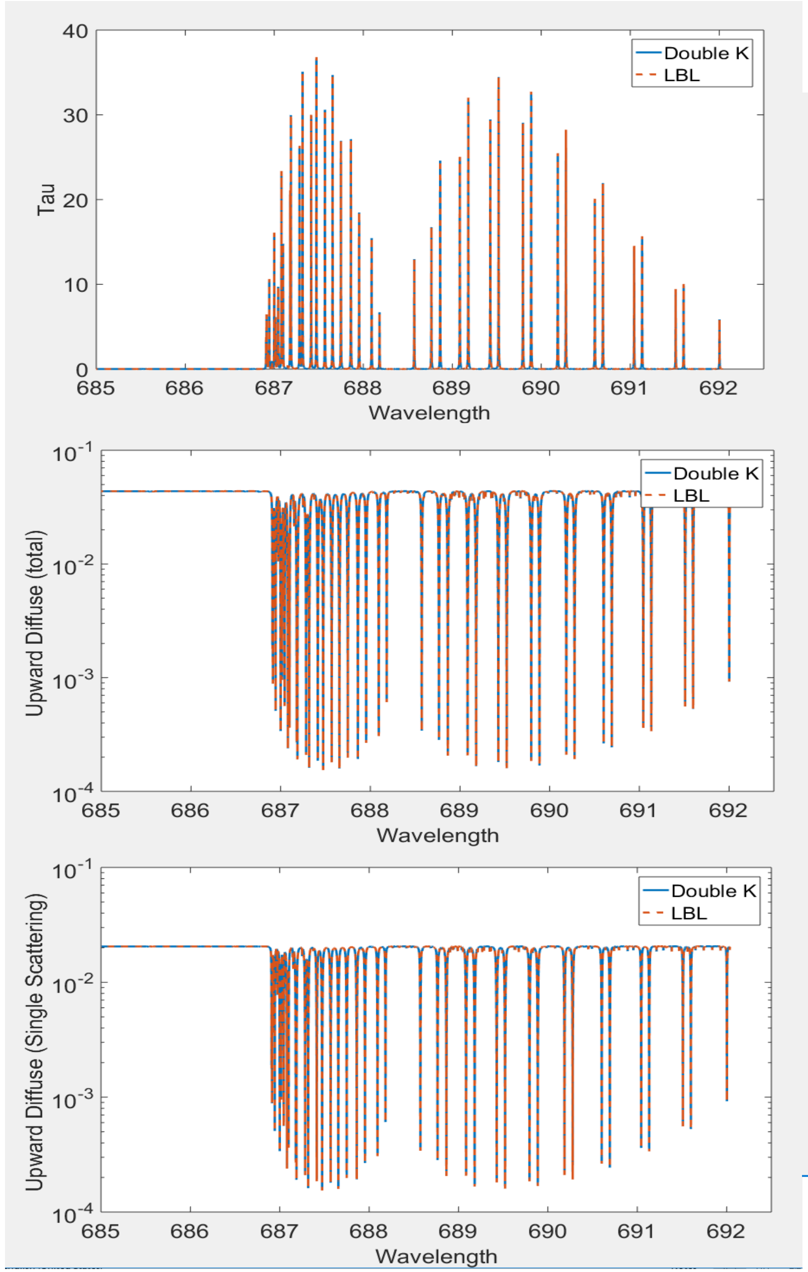


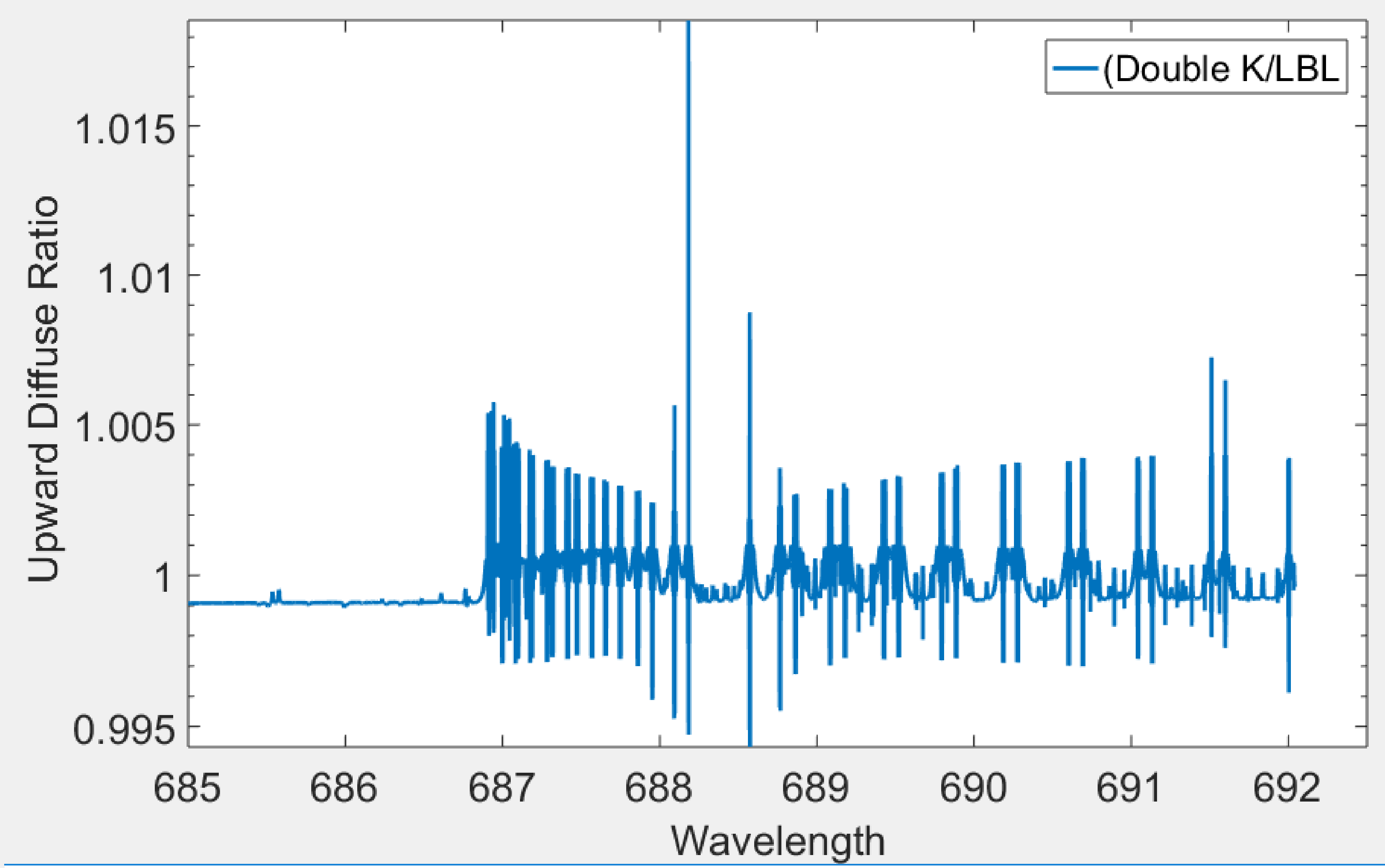


A fast RT model: results (A-band)



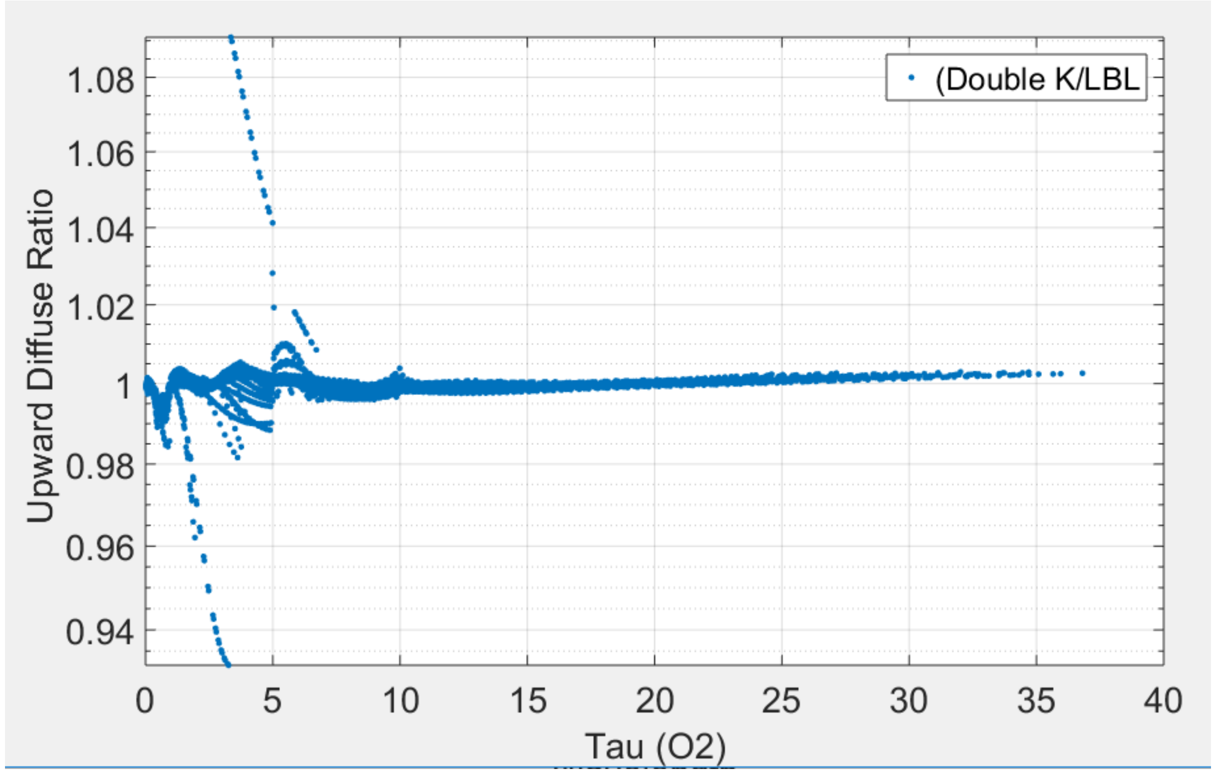
A fast RT model: results (B-band)--- clear sky

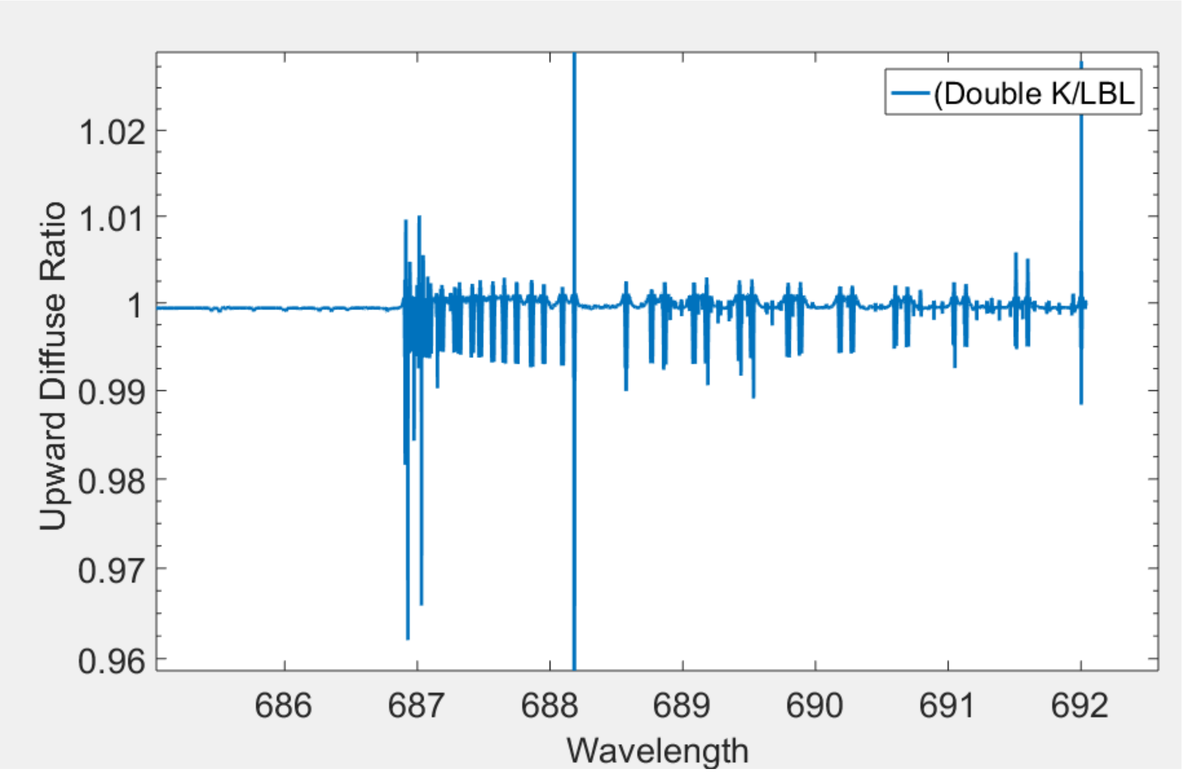




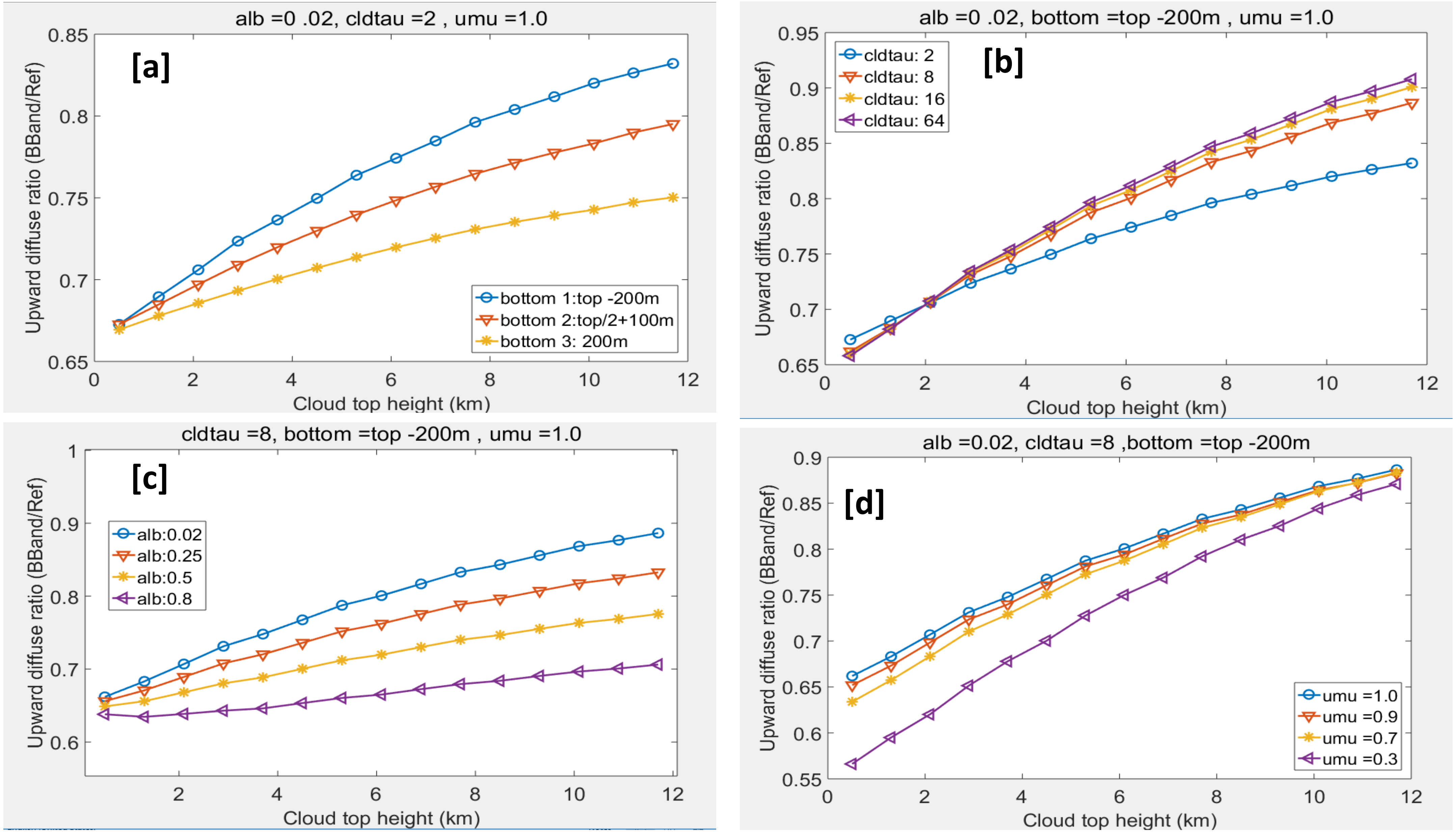
A fast RT model: results (B-band)

Cloud tau =2, 1.5~2.9 km





A fast RT model: results (B-band)



Summary:

- A fast radiative transfer model has been developed for simulating high-resolution oxygen B-band absorption band.

- The first order scattering radiance is calculated accurately by using a higher number of layers. The multiple-scattering component is extrapolated and/or interpolated from a finite set of calculations in the space of two integrated gaseous absorption optical depths to the wavenumber grids: a double-k approach.

- The double-k approach substantially reduces the error due to the uncorrelated nature of overlapping absorption lines: an accuracy of 0.5% for most applications under all-sky conditions and 1.5% for the most challenging multiple-layer cloud systems (99% of spectrum below 0.5%).

- This results in around a hundred-fold time reduction with respect to the standard forward radiative transfer calculation. It provides a powerful tool for DSCOVR EPIC B-band observation data analysis.