The Sensitivity of Shortwave Radiative Forcing and Heating Rates to the Aerosol Vertical Profile

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Aerosol Radiative Forcing

$$F_{net} = F_{\downarrow} - F_{\uparrow}$$

$$ARF = F_{net}(with\ aerosol) - F_{net}(without\ aerosol)$$

- **Altitude:**
  - **Top of Atmosphere**
  - **Surface**
  - **Profile**
- **Averaging (or not)**
  - **Spectral and Broadband**
  - **Instantaneous and 24 hour**

Heating Rate

$$HR = \frac{\partial T}{\partial t} = -\frac{1}{\rho c_p}\frac{\partial F_{net}}{\partial z}$$

$$AHR = HR(with\ aerosol) - HR(without\ aerosol)$$

$F : Flux$

$ARF : Aerosol\ Radiative\ Forcing$

$AHR : Aerosol\ Heating\ Rate$

$T : Temperature$

$t : time, \quad z : Altitude$

$\rho : air\ density, \quad c_p : specific\ heat\ capacity$

INPUTS

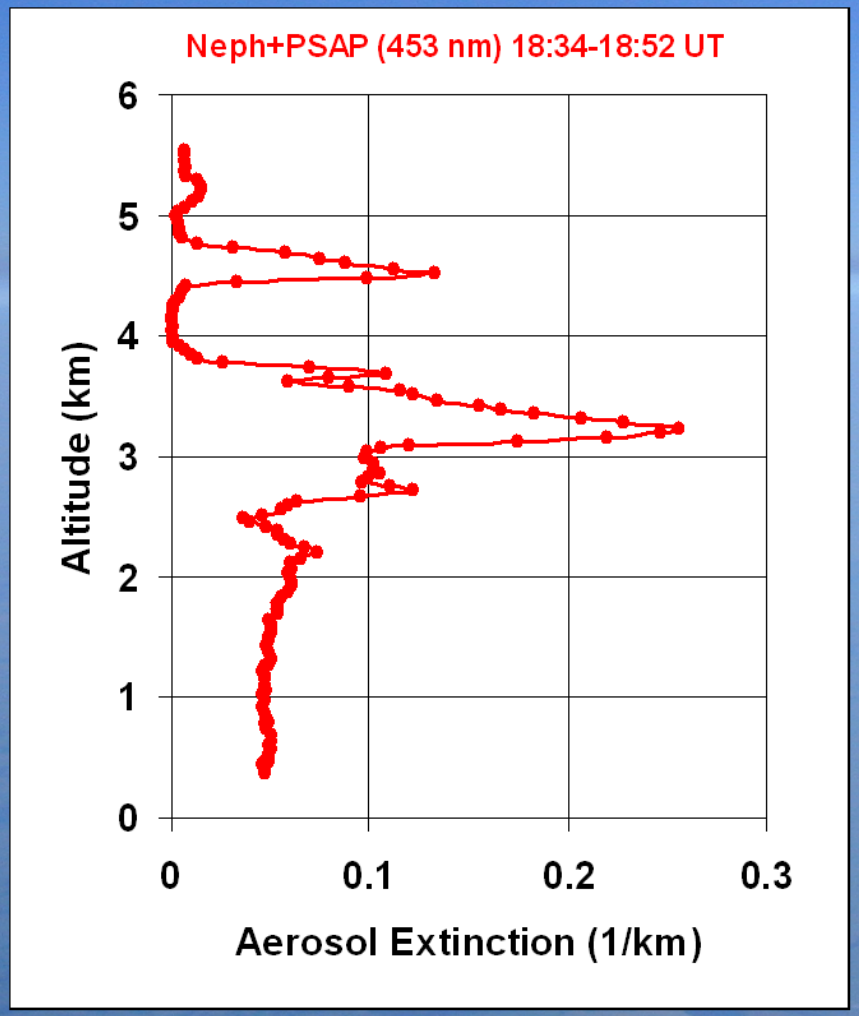
Profiles of:
Extinction, σ (λ)
Single Scattering Albedo, ω (λ)
Asymmetry Parameter, *g* (λ)
H_2O, O_3, p, T, other gases

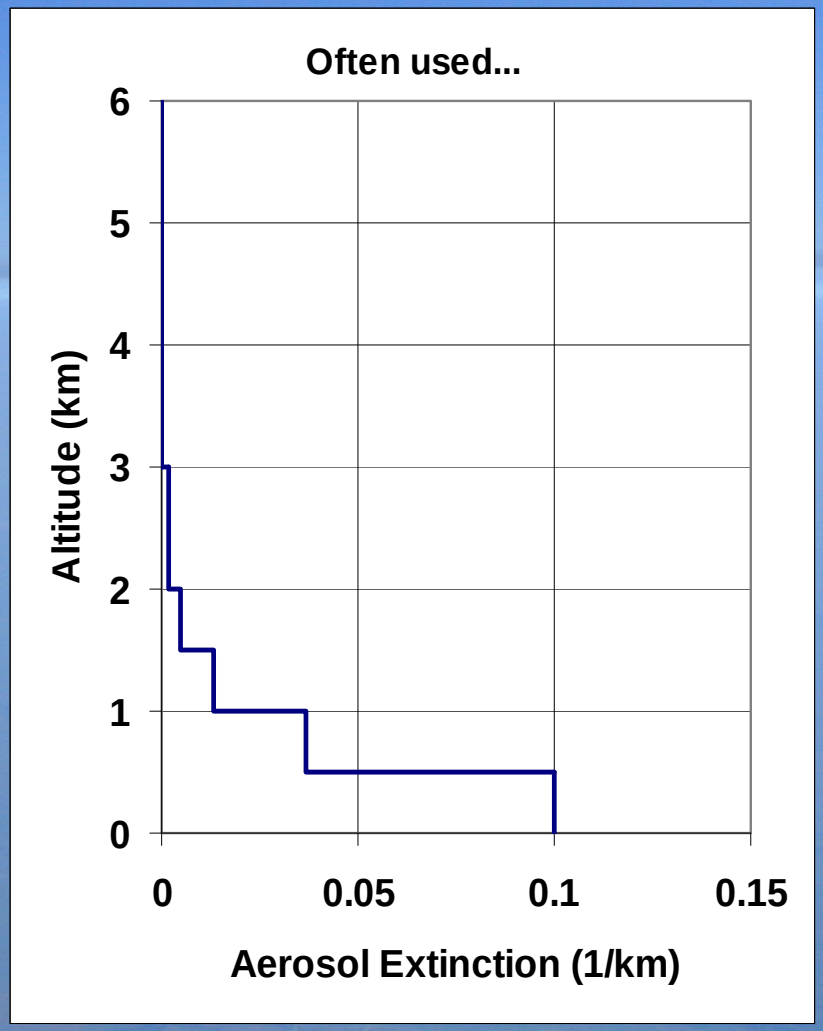
Surface Albedo, R (λ)
Solar Zenith Angle

Does the vertical profile of aerosol properties matter for the radiation budget?

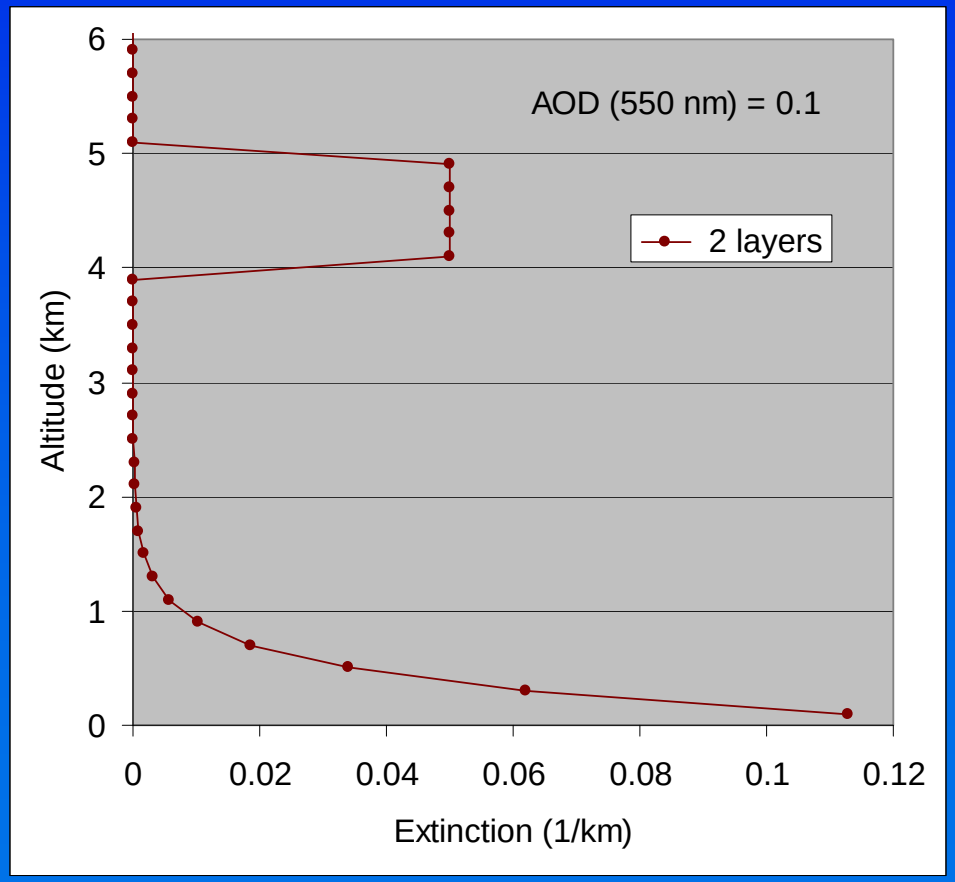
Siberian smoke over Oklahoma as seen from Twin Otter on May 27, 2003

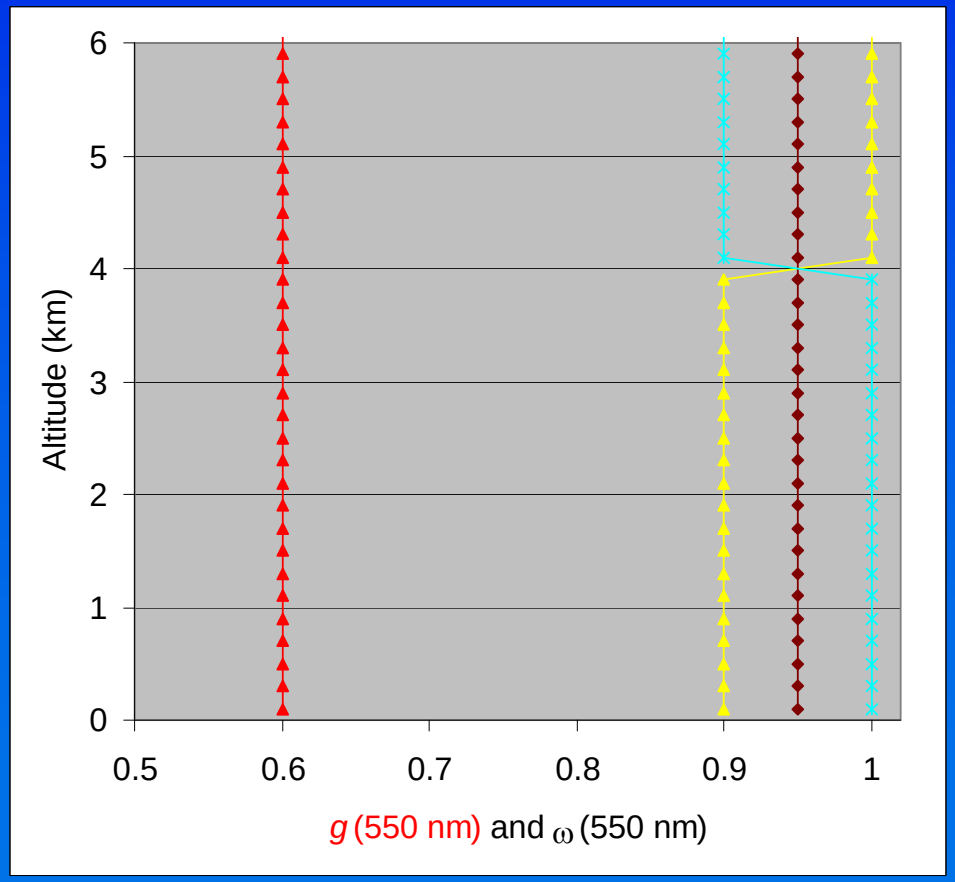
Photo courtesy of Roy Woods

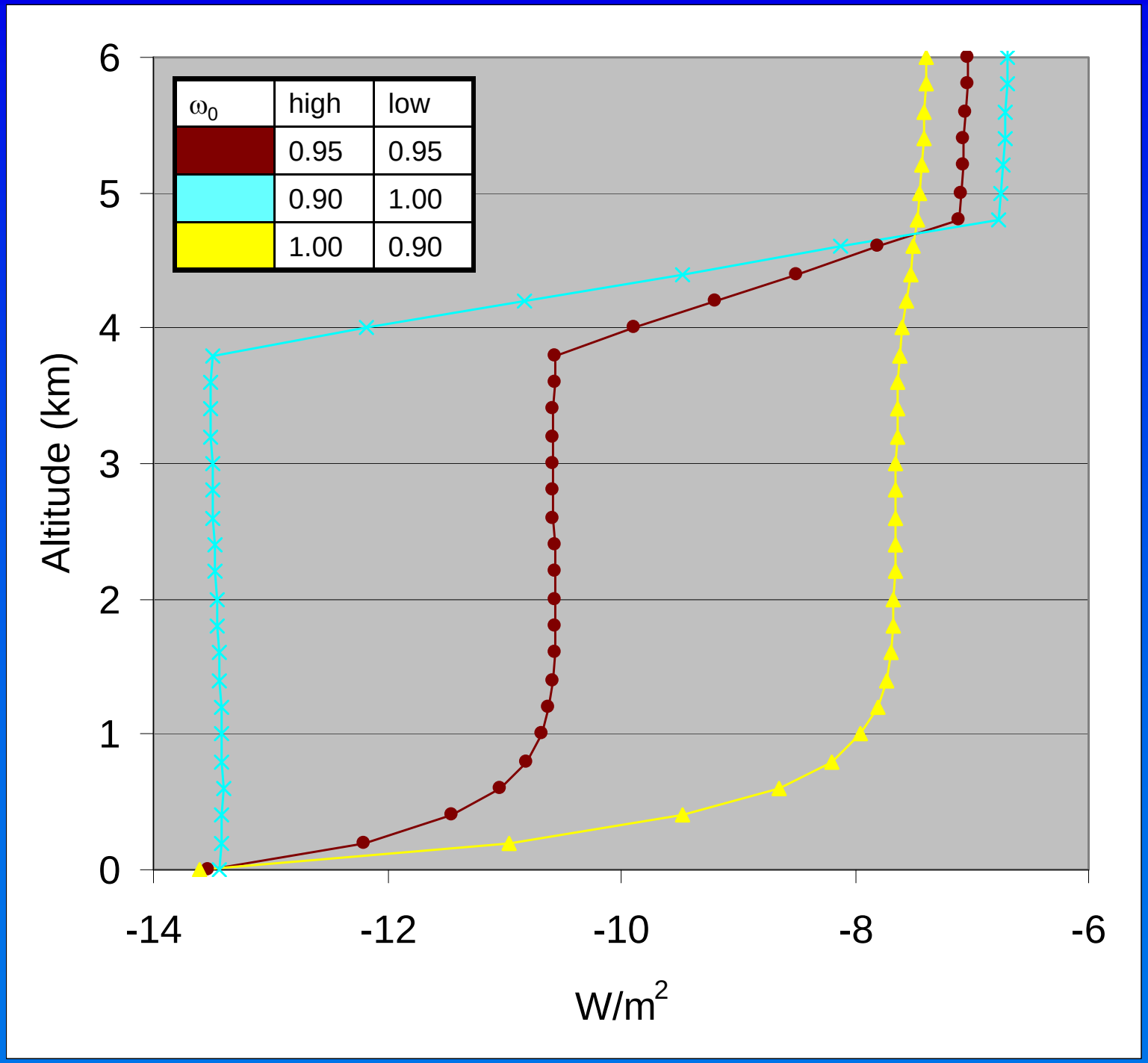


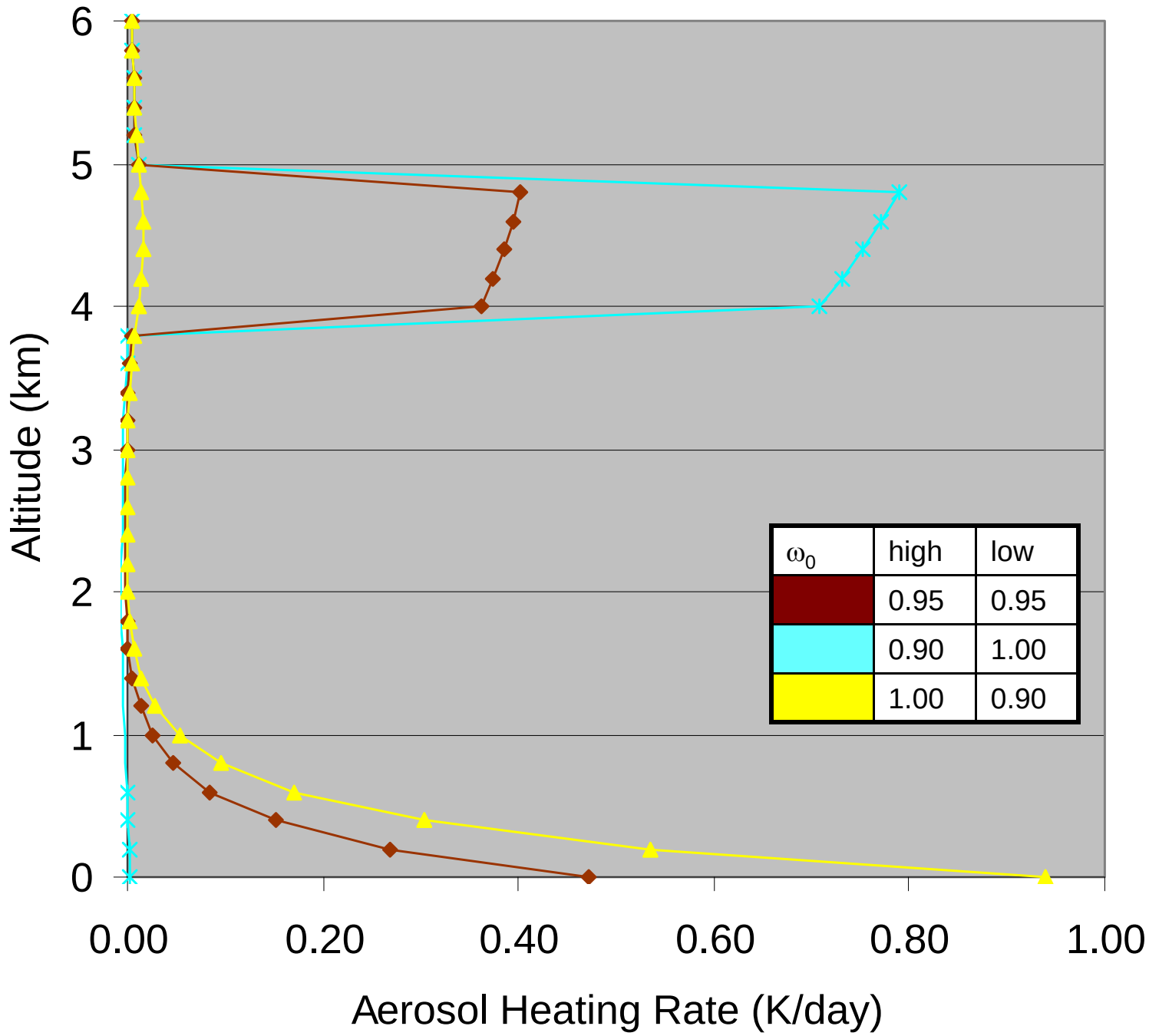


1. Idealized two-layer case

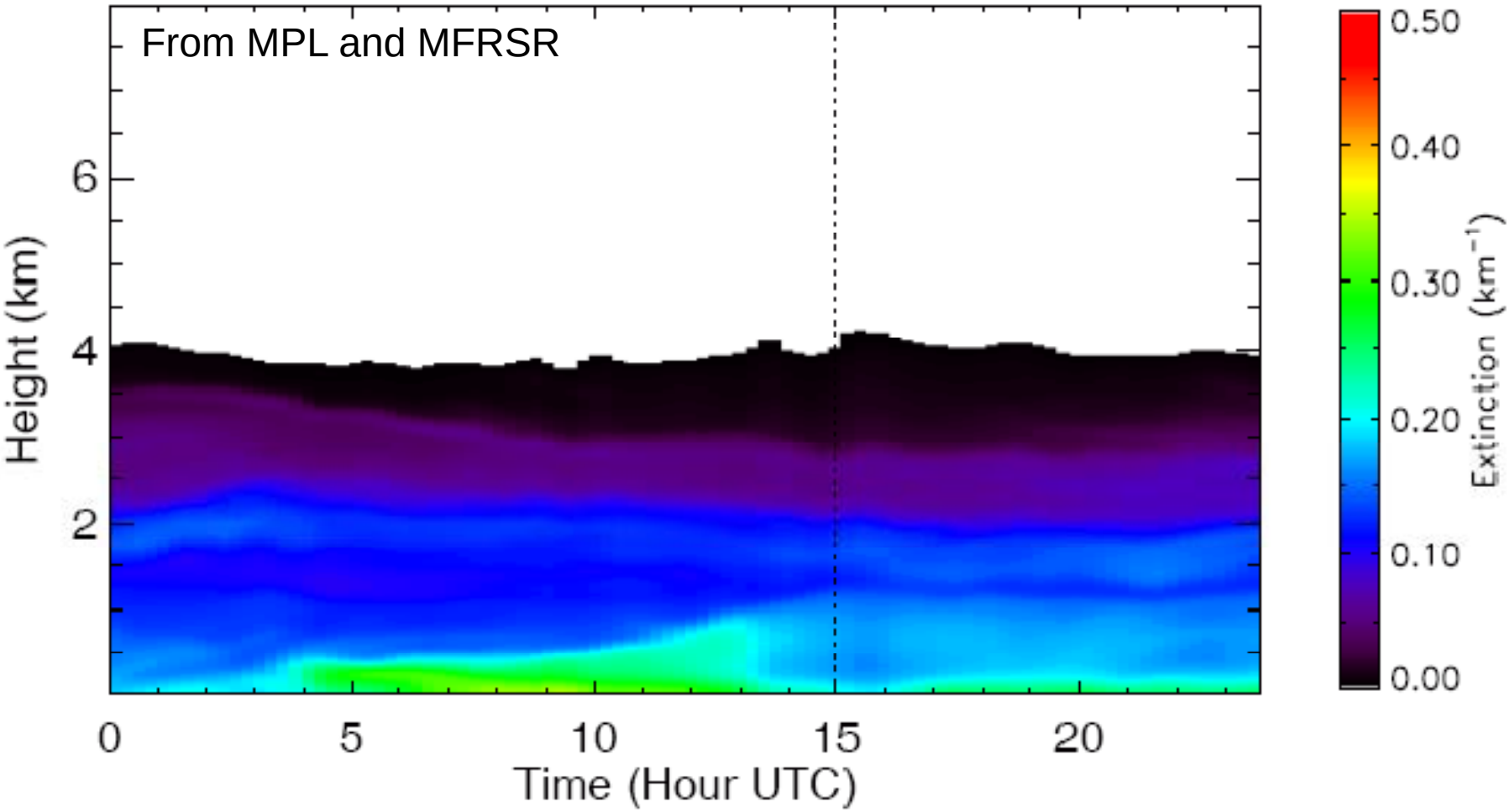


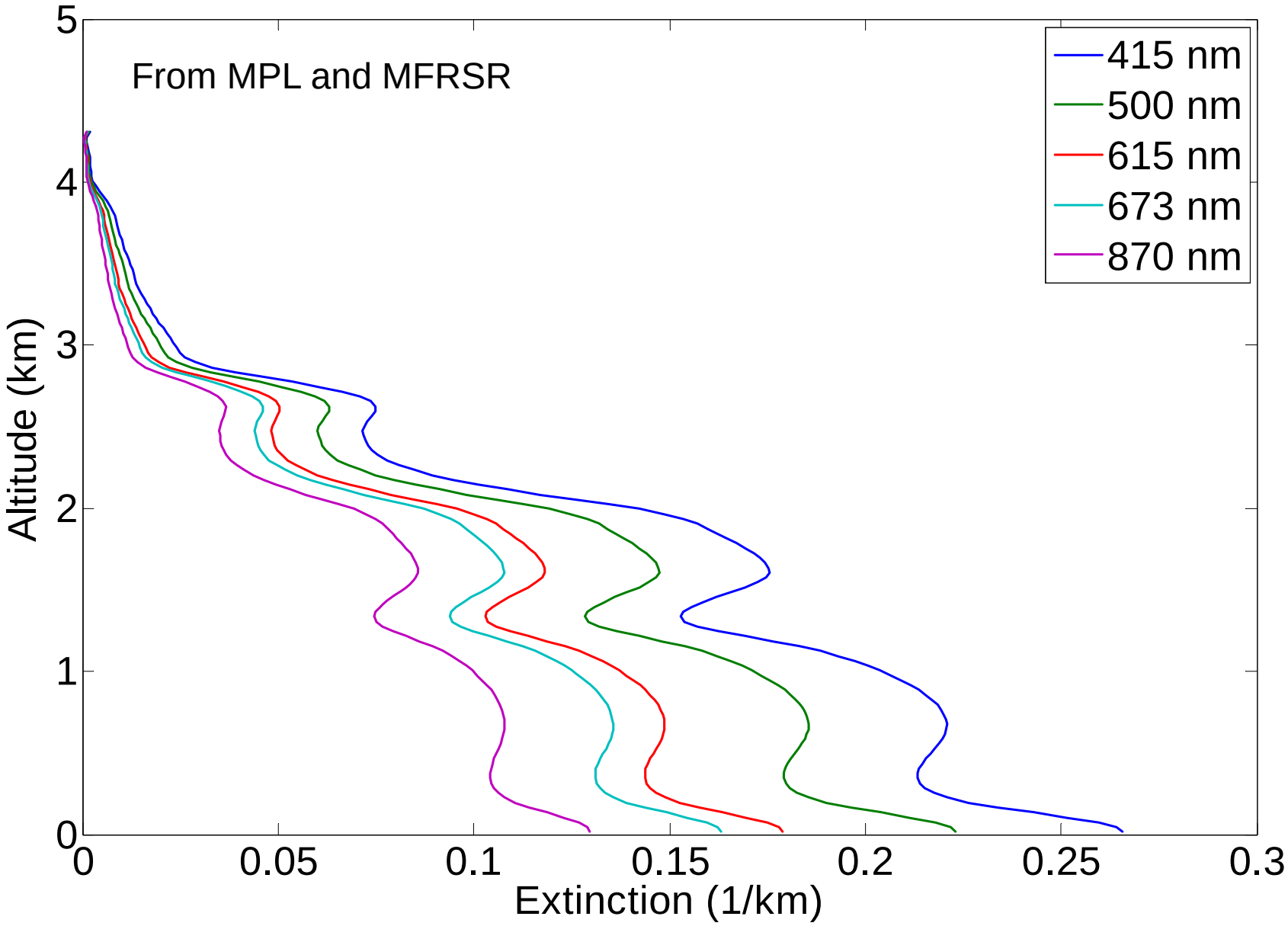


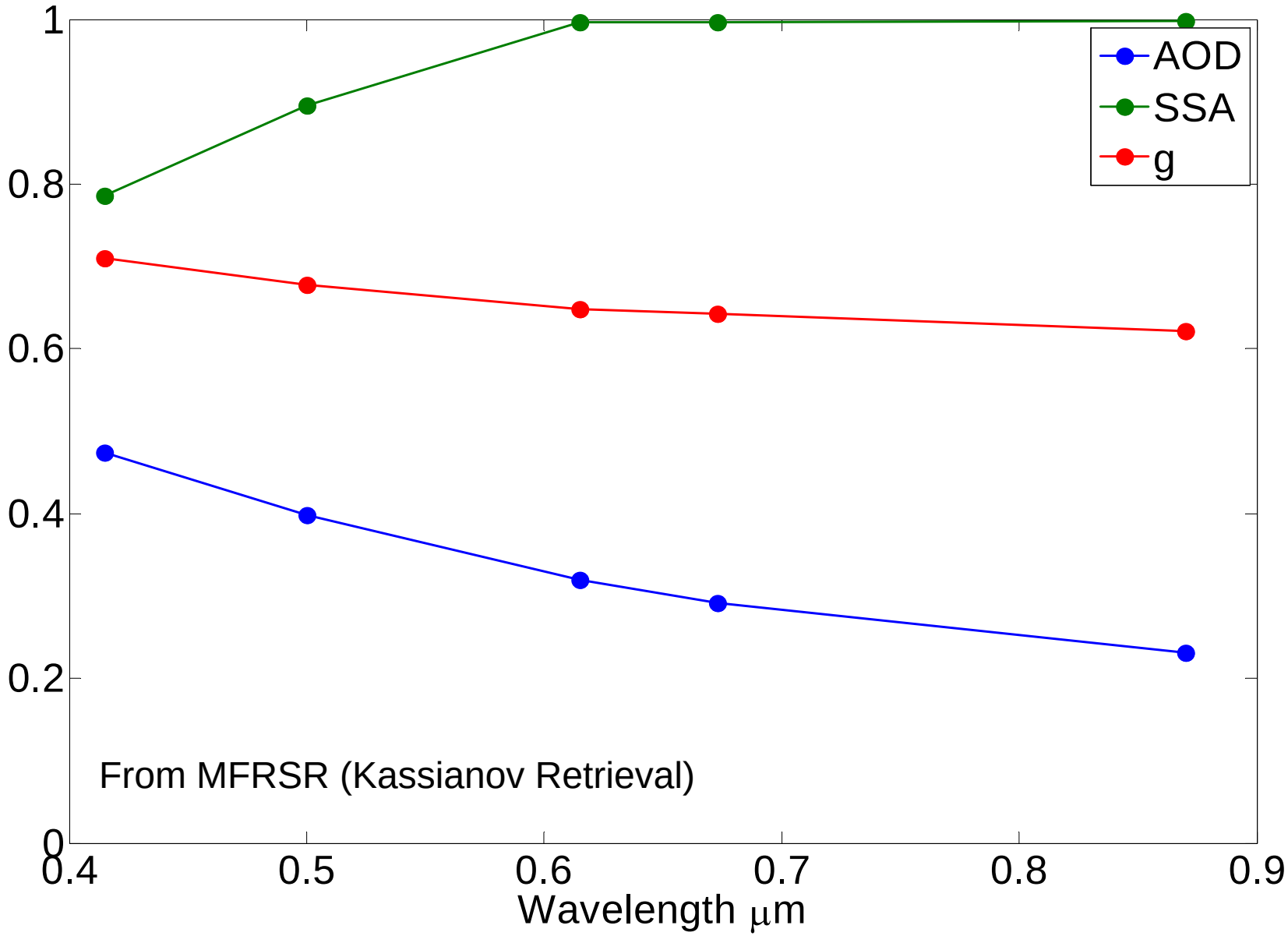

ω_0
high
low
0.95
0.95
0.90
1.00
1.00
0.90
Altitude (km)
0
1
2
3
4
5
6
-14
-12
-10
-8
-6
W/m^2

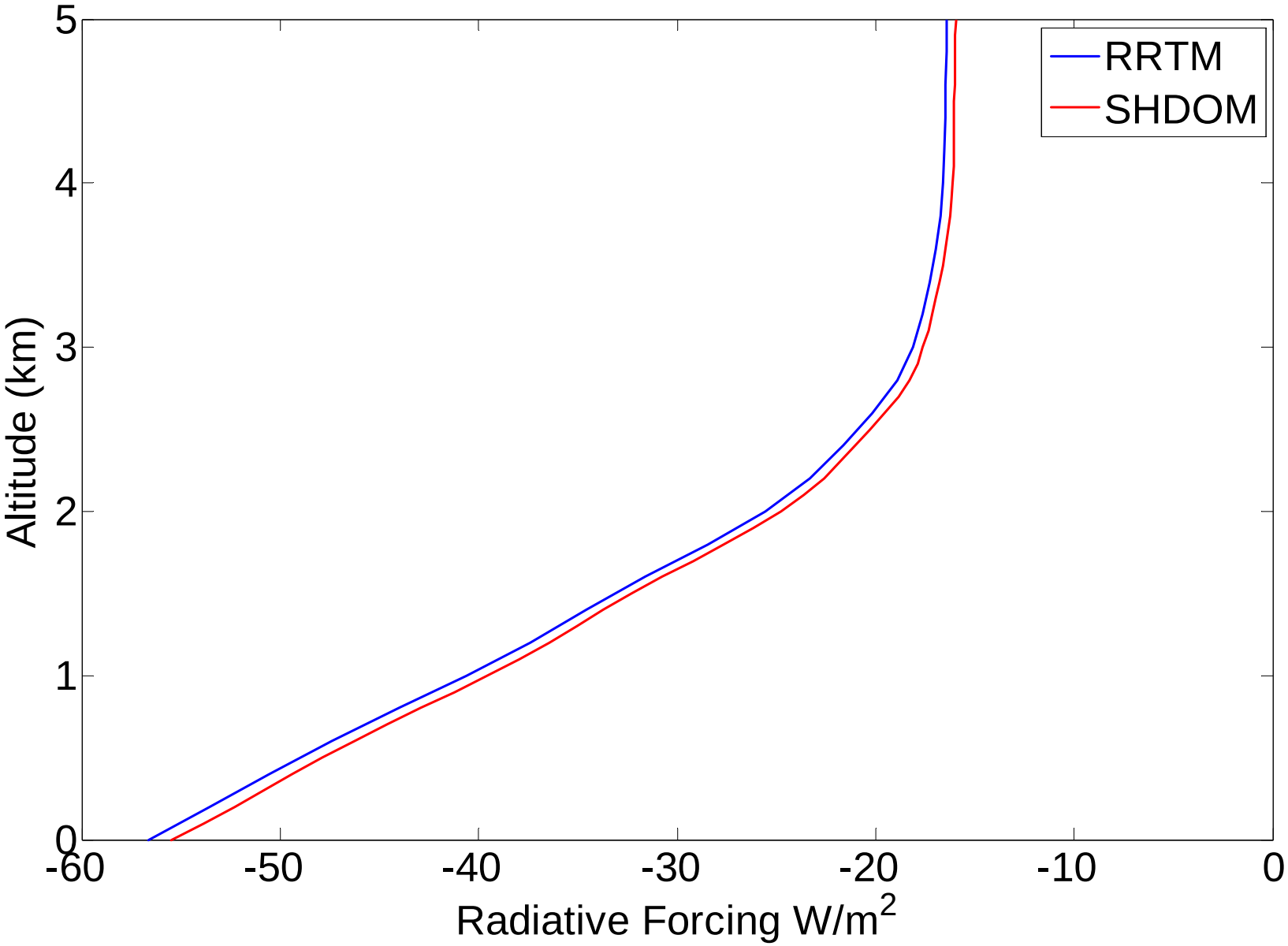

Altitude (km)
6
5
4
3
2
1
0
0.00
0.20
0.40
0.60
0.80
1.00
Aerosol Heating Rate (K/day)
ω0
high
low
0.95
0.95
0.90
1.00
1.00
0.90

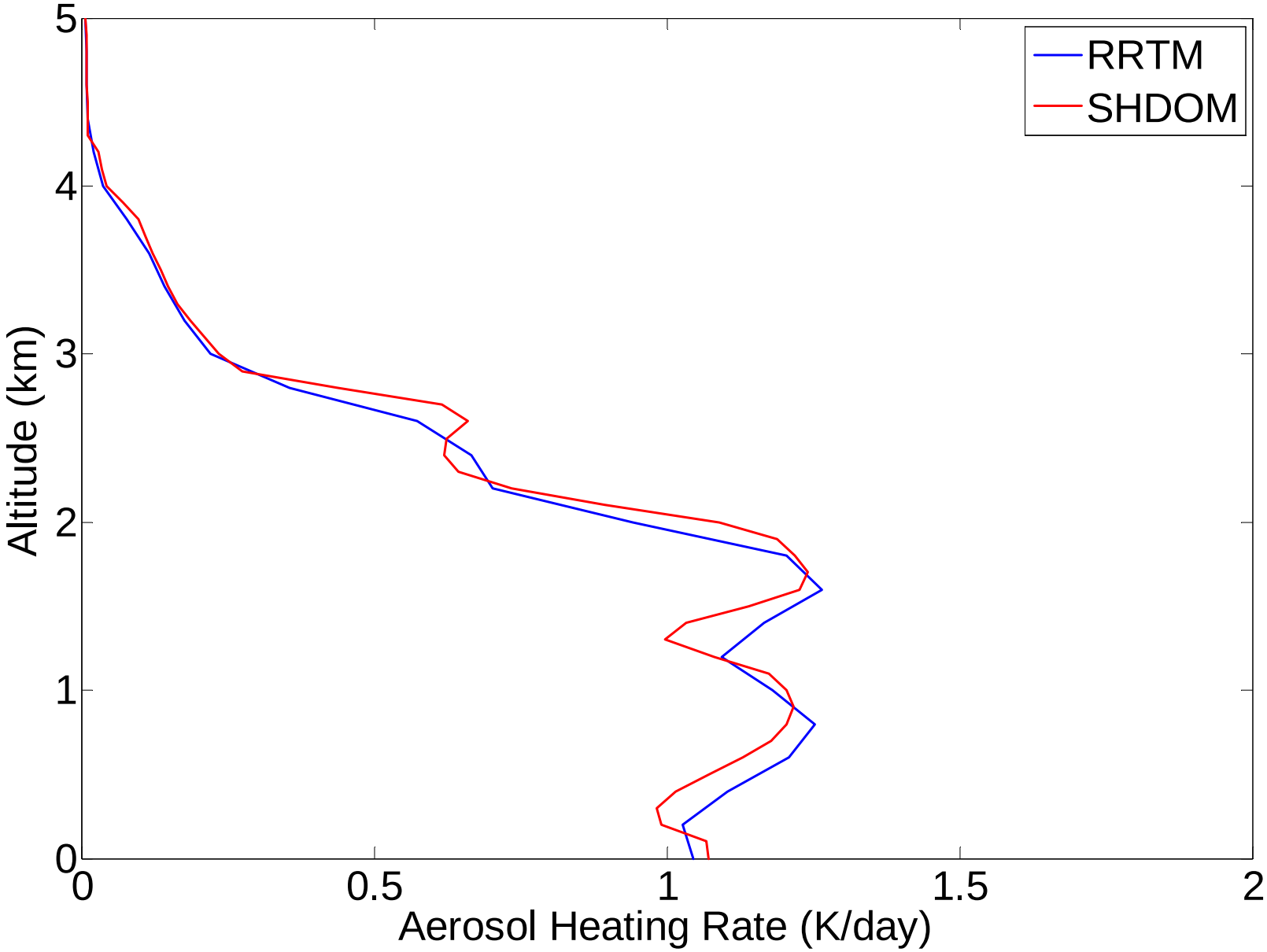
Real World Case 1:
Niamey, Niger
2 Jan 2006, 15 UTC, SZA 59º



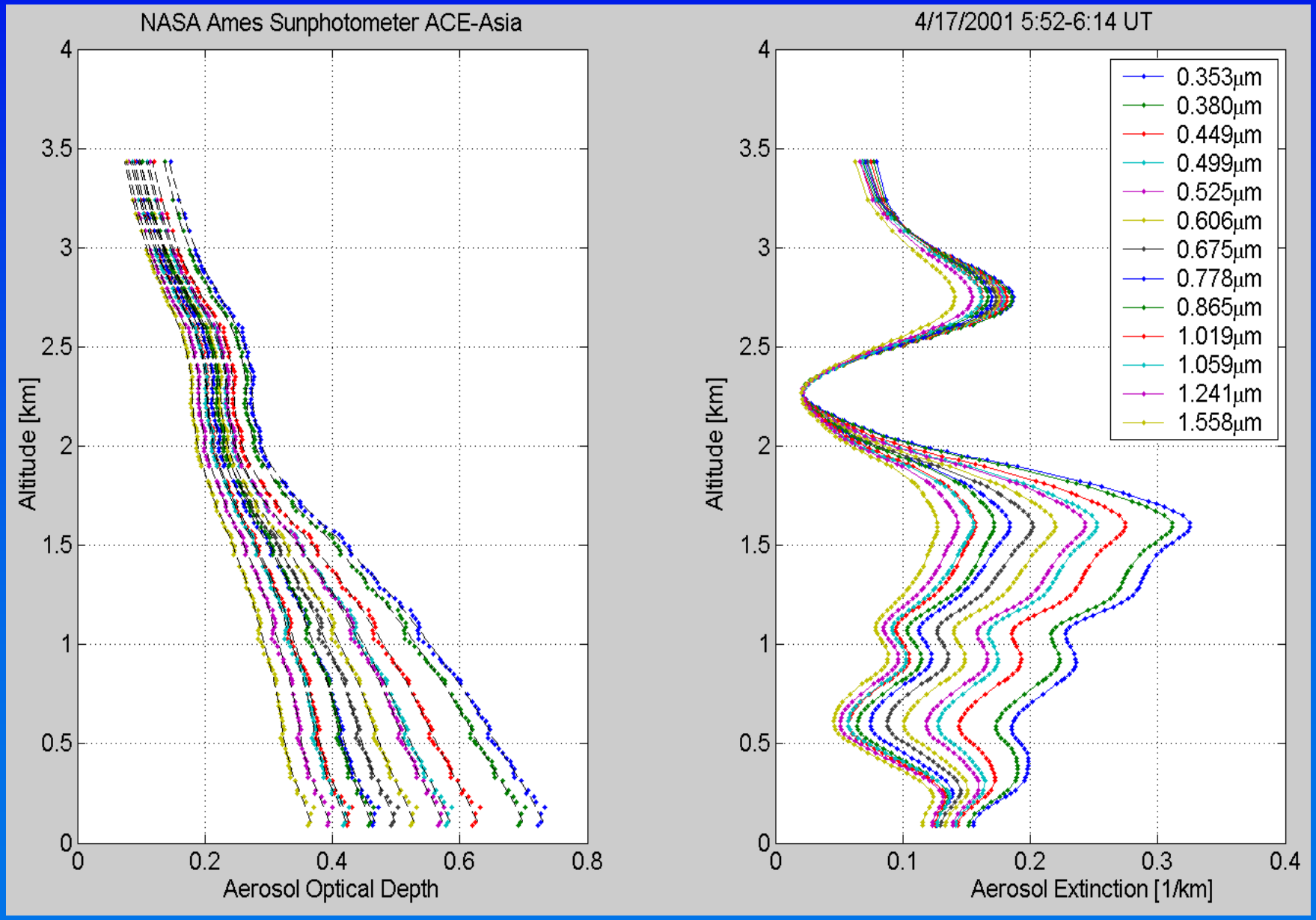

From MPL and MFRSR
415 nm
500 nm
615 nm
673 nm
870 nm
Altitude (km)
Extinction (1/km)
0
1
2
3
4
5
0
0.05
0.1
0.15
0.2
0.25
0.3


1
0.8
0.6
0.4
0.2
0
0.4
0.5
0.6
0.7
0.8
0.9
Wavelength μm
AOD
SSA
g
From MFRSR (Kassianov Retrieval)

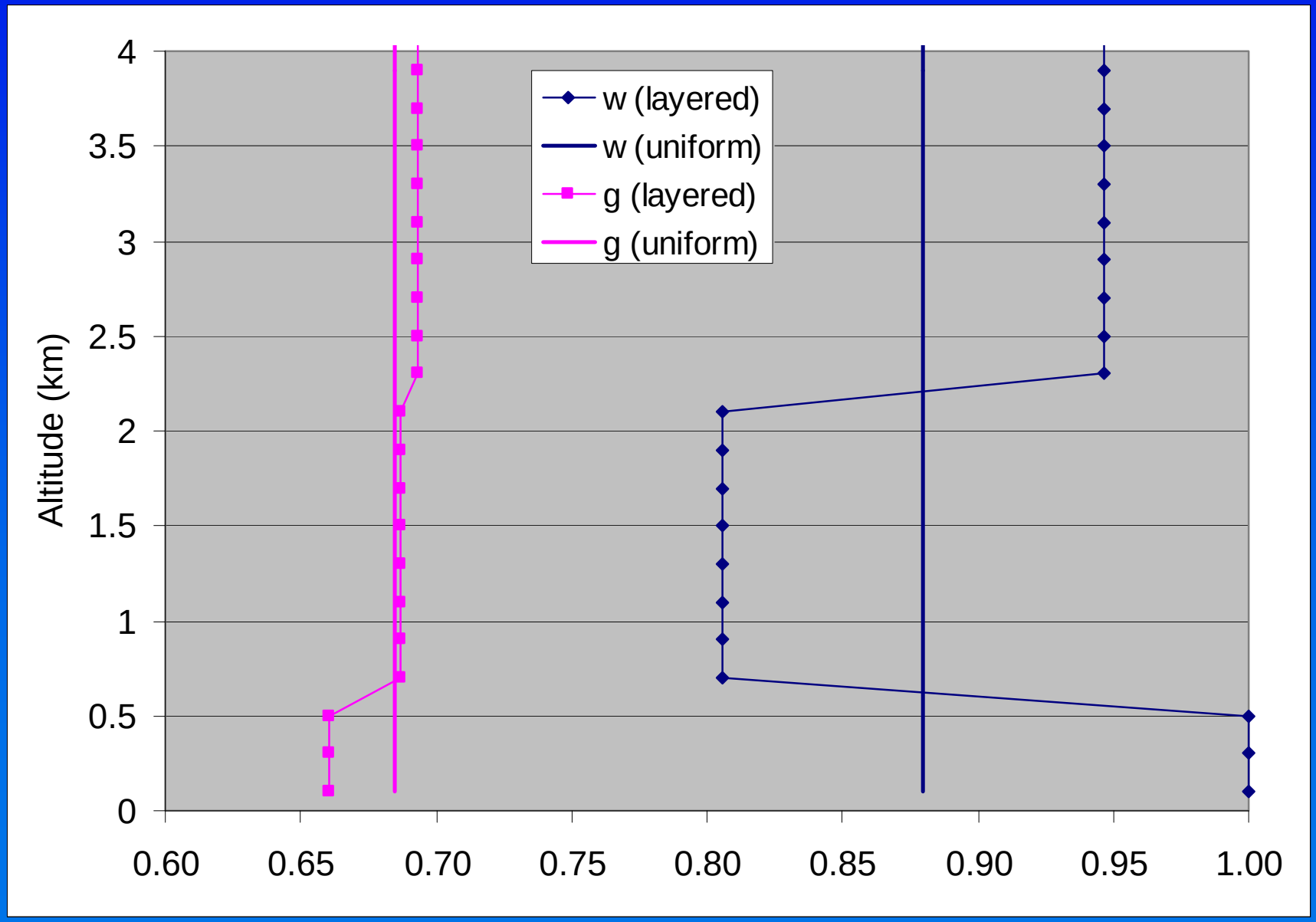

RRTM
SHDOM
Altitude (km)
Radiative Forcing W/m2
0
1
2
3
4
5
-60
-50
-40
-30
-20
-10
0

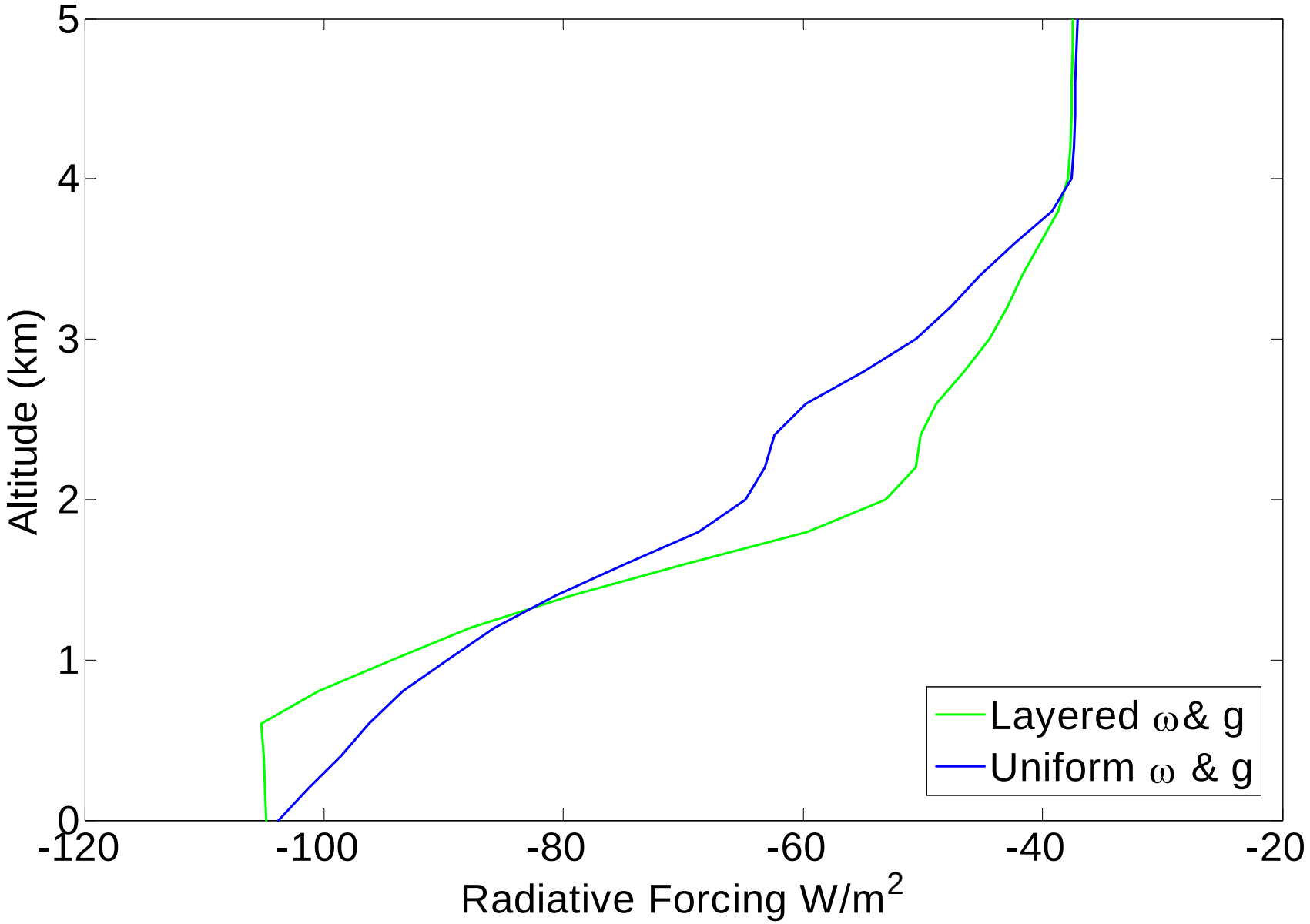

RRTM
SHDOM
Altitude (km)
Aerosol Heating Rate (K/day)
0
1
2
3
4
5
0
0.5
1
1.5
2

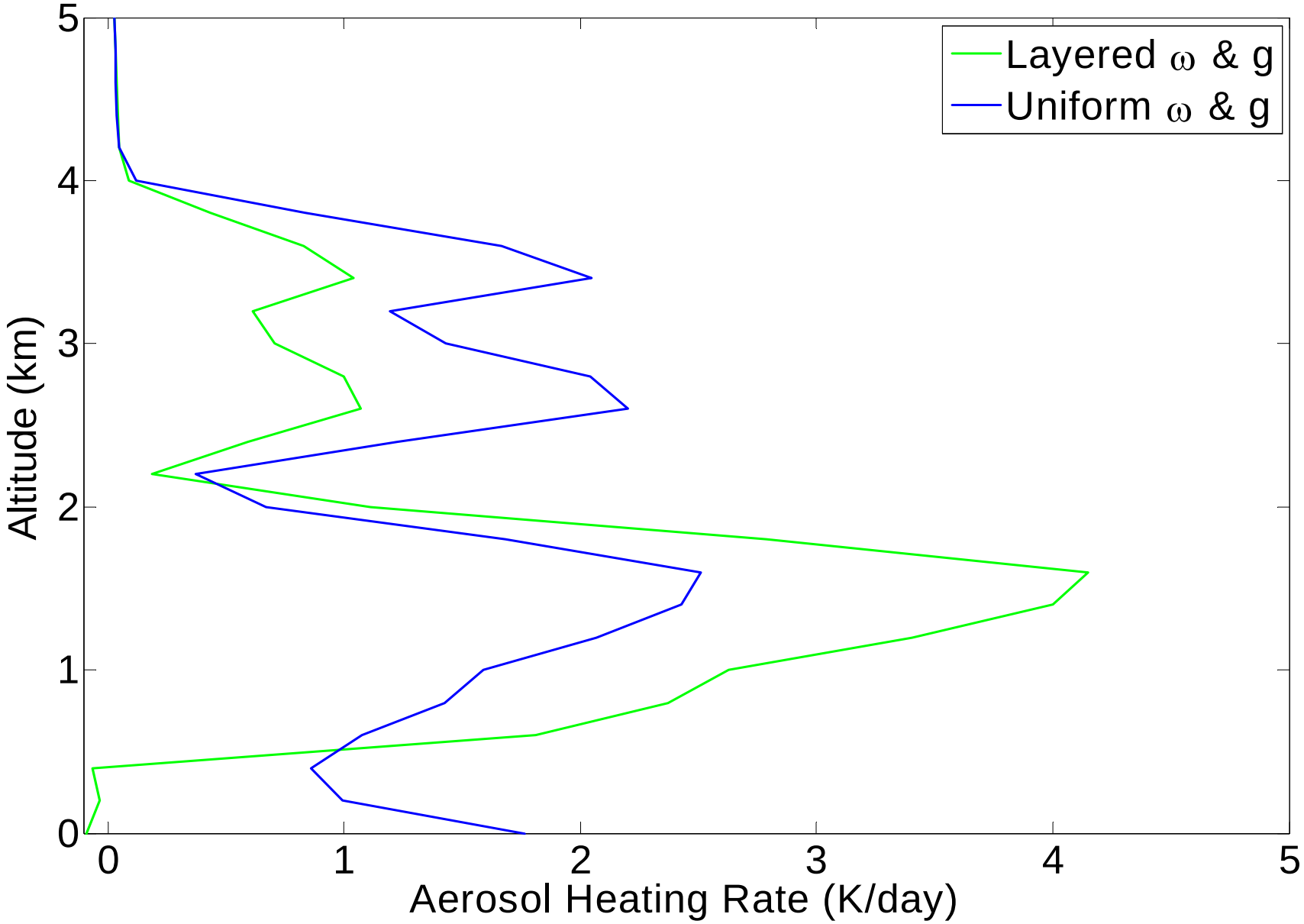
Case 2: ACE-Asia, Sea of Japan



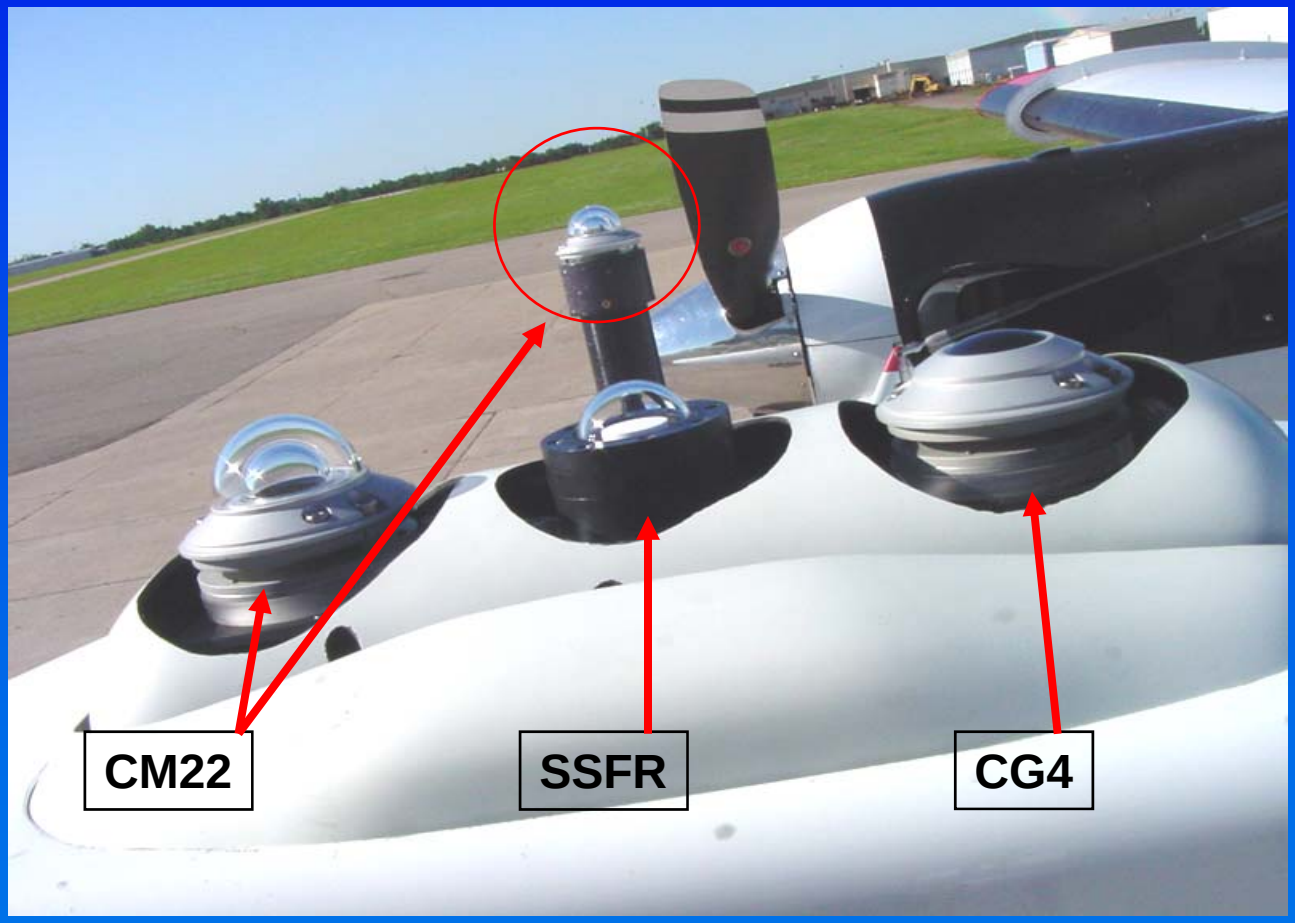
Input profiles of ω and *g*



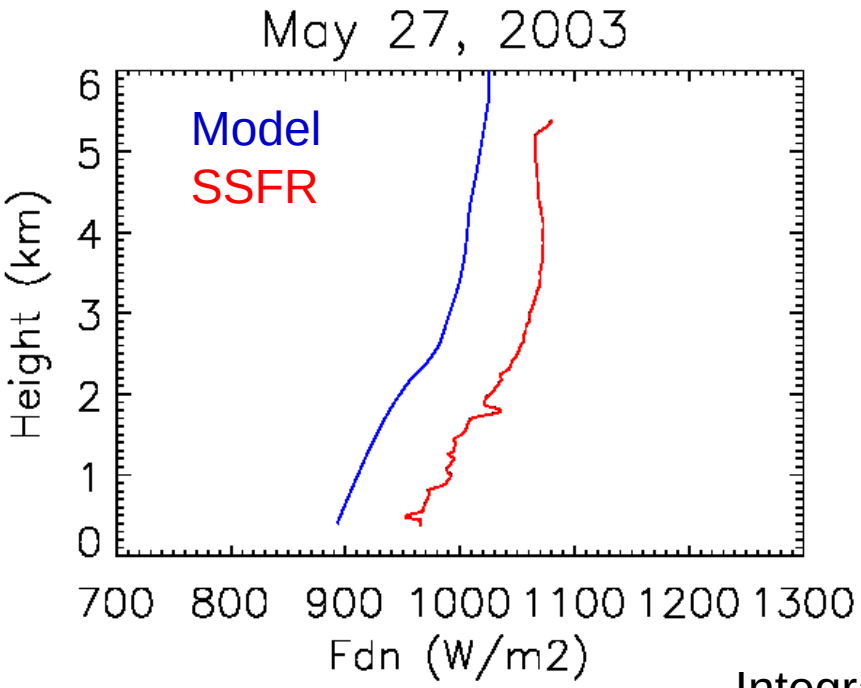

5
4
3
2
1
0
Altitude (km)
-120
-100
-80
-60
-40
-20
Radiative Forcing W/m2
Layered ω& g
Uniform ω & g

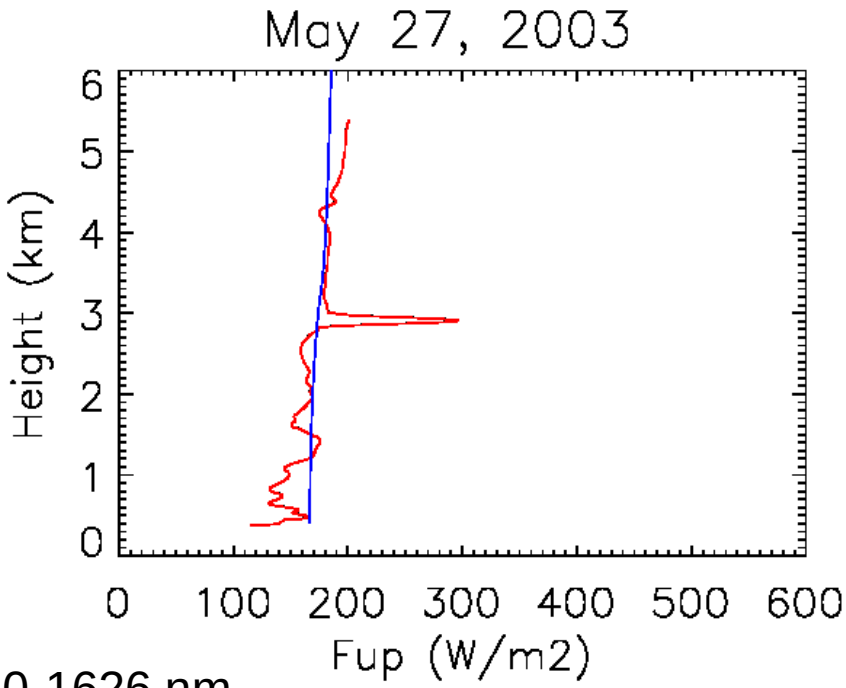

Layered ω & g
Uniform ω & g
Altitude (km)
Aerosol Heating Rate (K/day)
0
1
2
3
4
5
0
1
2
3
4
5

Can we measure the radiative forcing profile?

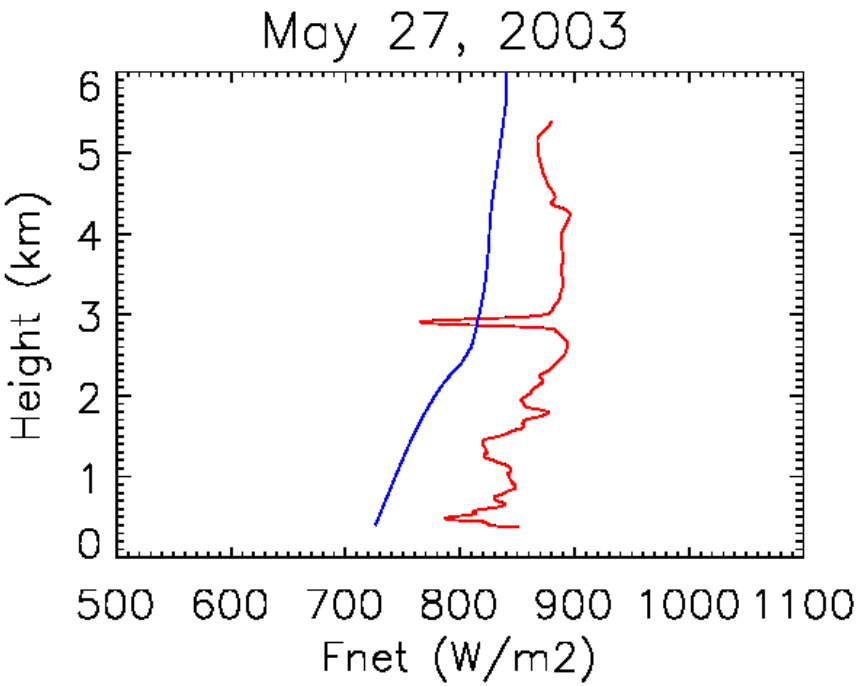


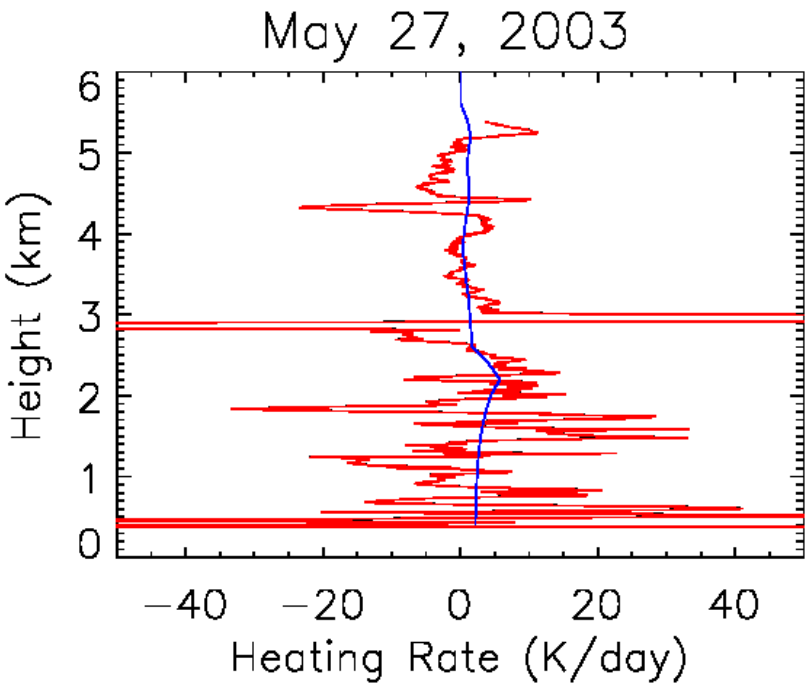
Same radiometer set on belly of Twin Otter for upwelling flux





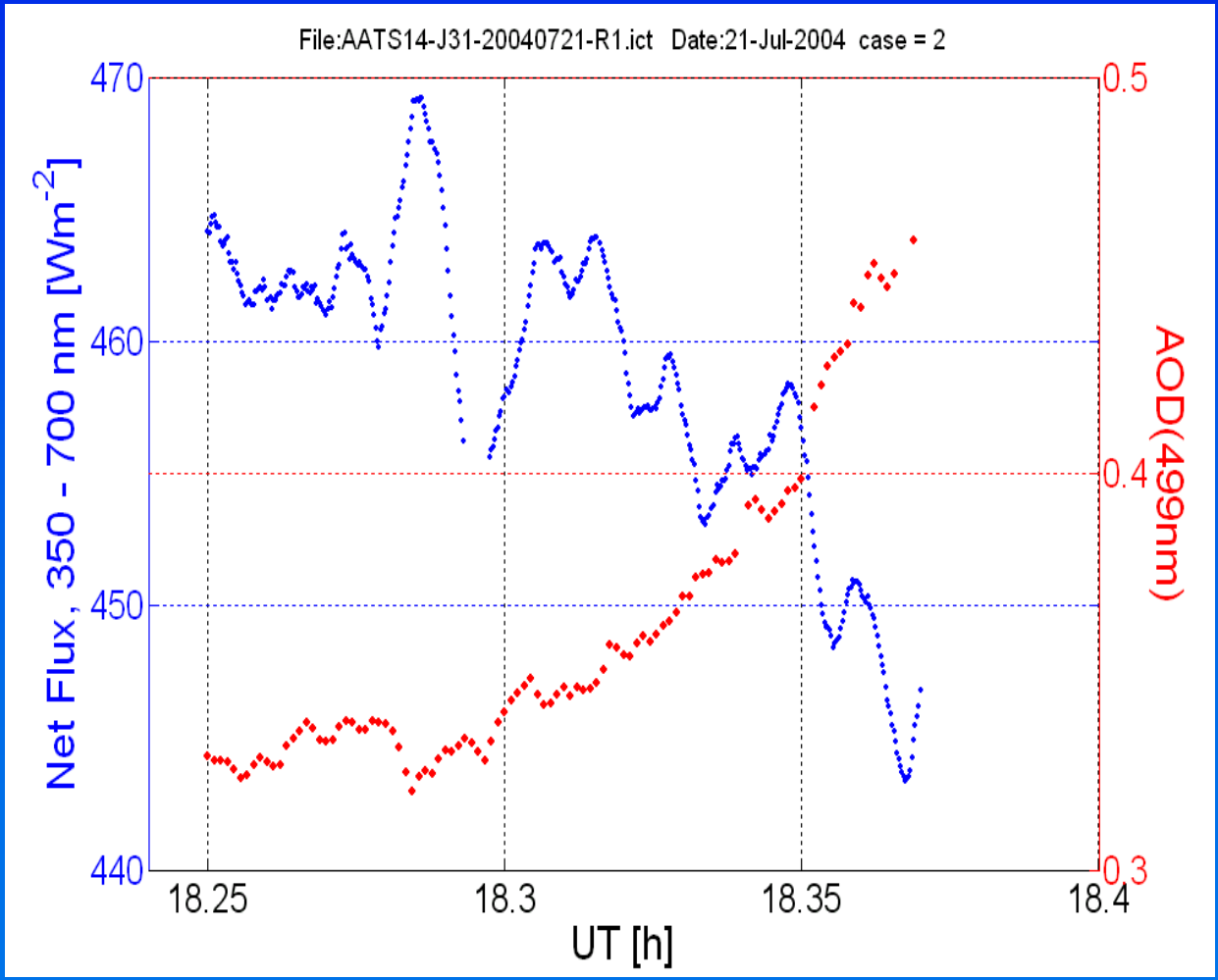
Integrated 380-1626 nm

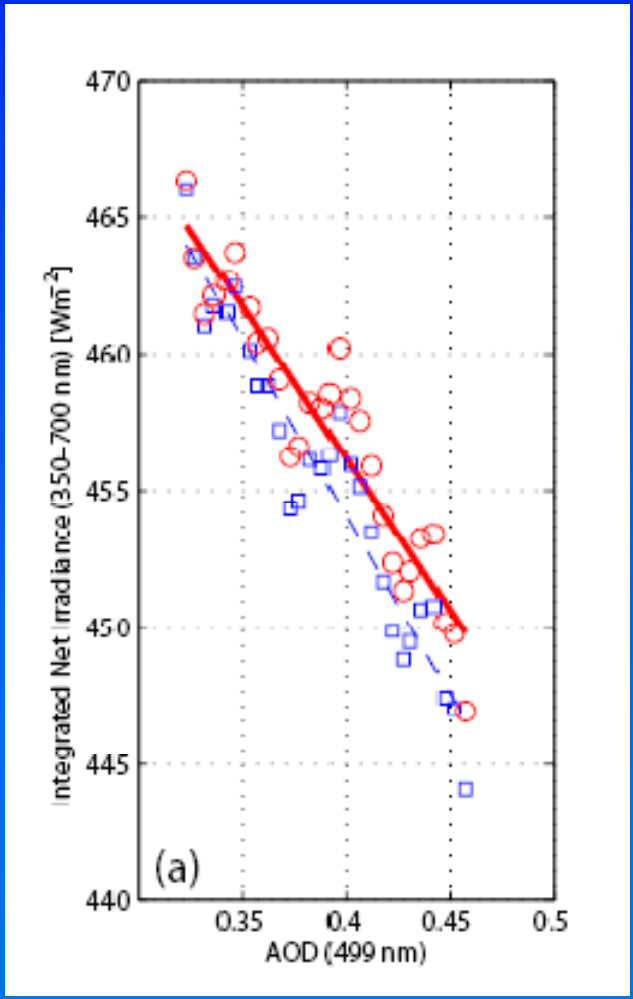




Airborne measurements of spectral direct aerosol radiative forcing

Gulf of Maine





Redemann et al., JGR, 2006