# The Effect of Wavelength Binning on Solar Irradiance Extinction Altitude by Atmospheric Ozone Absorption

LASP 2007 REU

Research By: Jonathan C. Ruel
Mentor: Martin Snow

EMBRY-RIDDLE AERONAUTICAL UNIVERSITY

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UNIVERSITY OF COLORADO AT BOULDER

Jonathan C. Ruel
Embry-Riddle Aeronautical University



# Outline

- Introduction
- Basic Atmospheric Model
- SSI Data
- Optical Depth
- Solar Energy Penetration
- Results and Conclusions
- Future Research

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# Introduction

- National Center for Atmospheric Research
  - CCM2 and CAM3
- δ-Eddington approximation
  - Binning of the solar spectrum
  - 8 bins between 200 and 700 nm
- This analysis compares the solar irradiance penetration at 1nm wavelength resolution to the bin-averaged irradiance spectrum.

| Bin | λ min (nm) | λ max (nm) |
|---|---|---|
| 1 | 200 | 245 |
| 2 | 245 | 265 |
| 3 | 265 | 275 |
| 4 | 275 | 285 |
| 5 | 285 | 295 |
| 6 | 295 | 305 |

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# Basic Atmospheric Model

- Focus was specifically on absorption due to atmospheric ozone
- Required finding an accurate ozone density profile
- The SpectralCalc[1] website provided:
  - Assumed an atmosphere in mid-latitude summer conditions
  - Temperature and pressure profiles
  - Mixing ratios of $O_3$ with altitude
- Used these to create a 1-dimensional atmosphere
- Interpolation performed
  - Profile data in 1 km increments from 0 to 120 km
- Total atmospheric number density profile obtained using the ideal gas law:

$$\frac{N}{V} = \frac{P(z)}{kT(z)}$$

- Ozone number density profile obtained by multiplying by the $0_3$ mixing ratios

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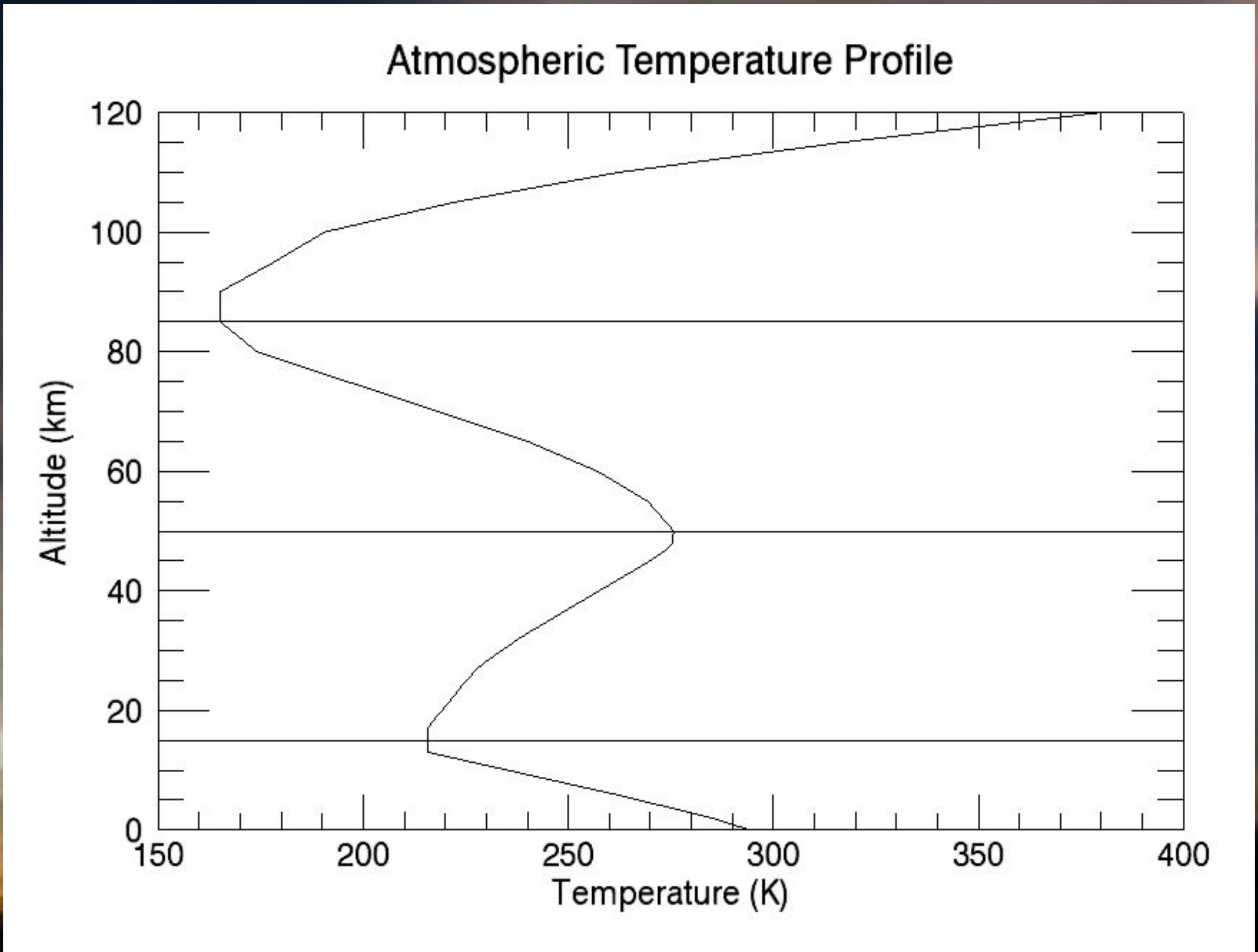
# Basic Atmospheric Model



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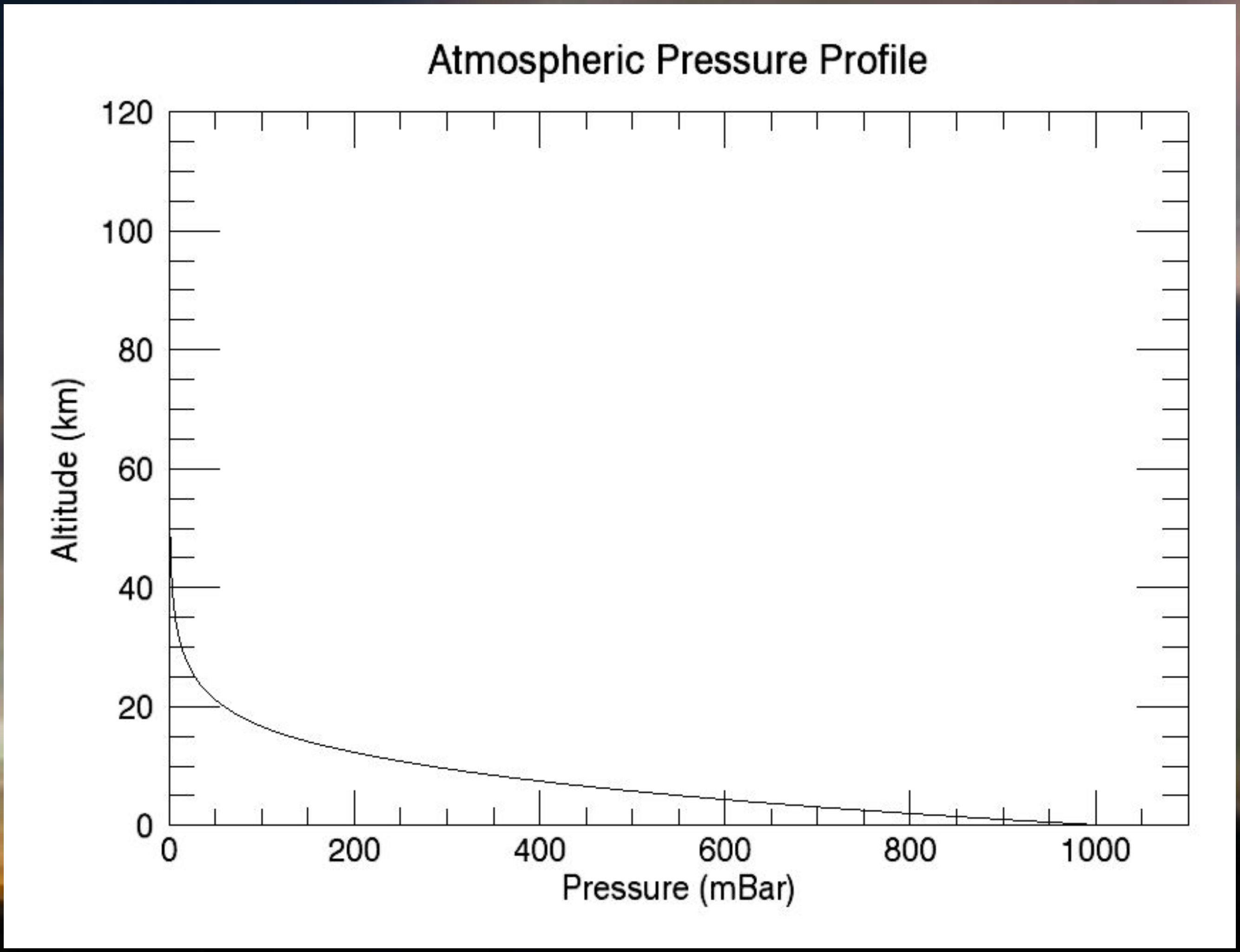

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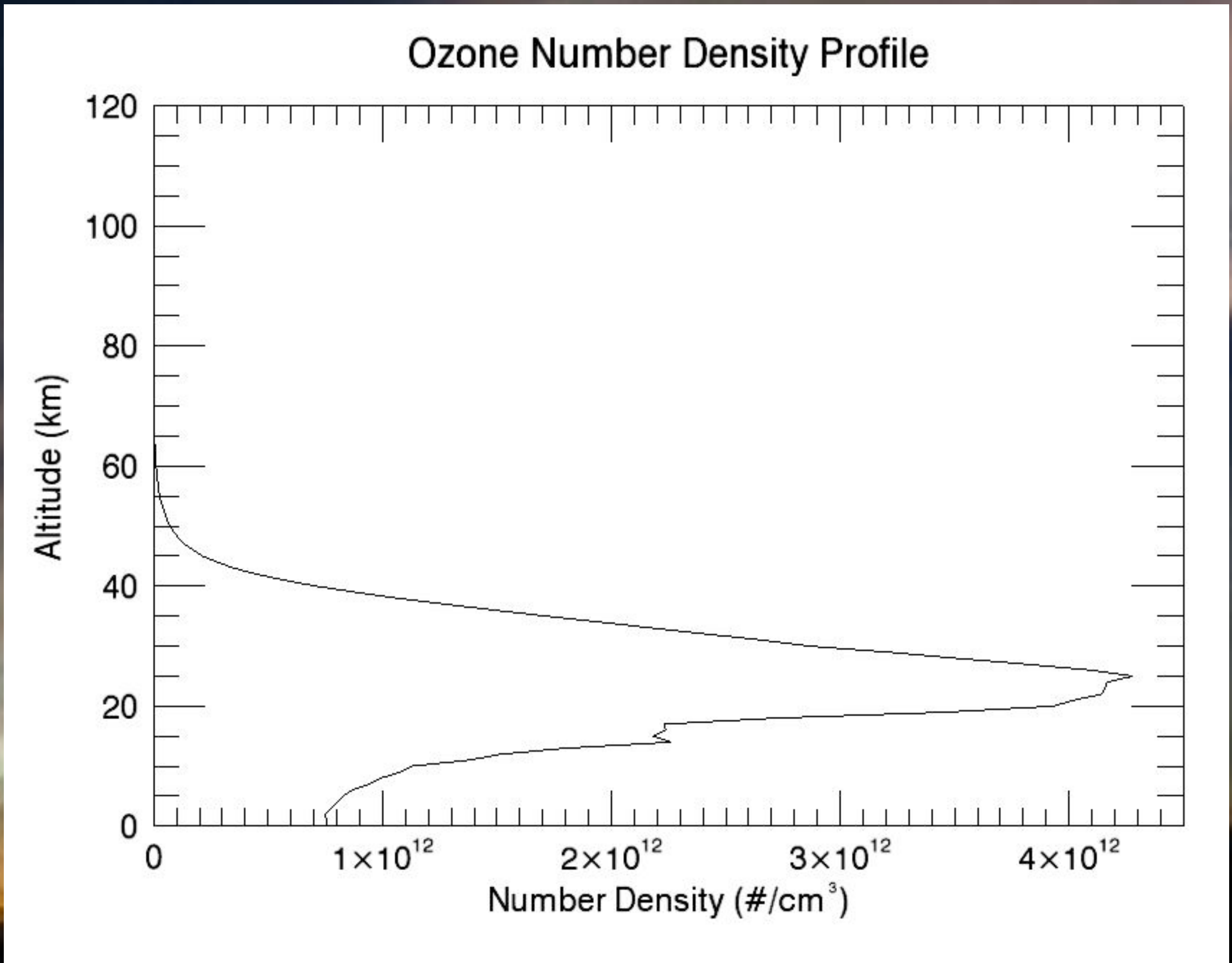

# Solar Spectral Irradiance

- SOLSTICE instrument on the SORCE spacecraft
- Obtained through the LISIRD[5] webpage
- SOLSTICE only sensitive up to 316 nm
  - Middle of the 7th bin (305 – 350 nm)
  - Irradiance values taken between 200 and 305 nm
- Data was averaged over each of the bins

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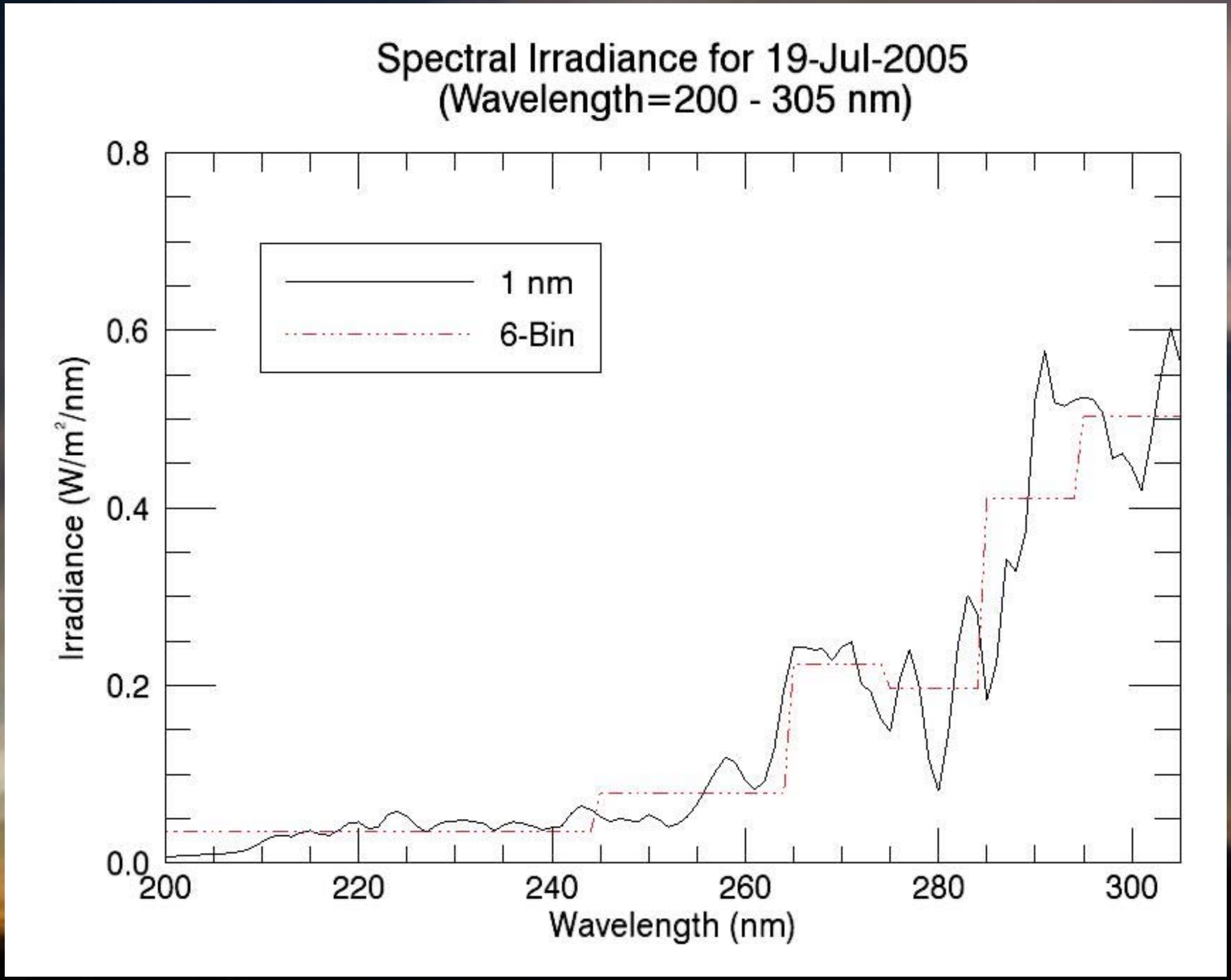
# Solar Spectral Irradiance



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# Optical Depth

- The amount of energy absorbed or transmitted through a medium is directly related to the optical depth, or opacity, of the medium
- Optical depth is both a function of altitude and wavelength (via the absorption cross section)
- JPL[3] gives the $0_3$ spectral absorption cross section
  - Reference temperature of 273 K
  - Another interpolation needed in order to achieve cross section values at 1 nm intervals between 200 and 305 nm
- With the appropriate absorption cross section and number density profiles, the optical depth was calculated using the equation:

$$\tau = \sigma \int_{z_0}^{\infty} n \, dz$$

- Each altitude and wavelength has it's own optical depth value

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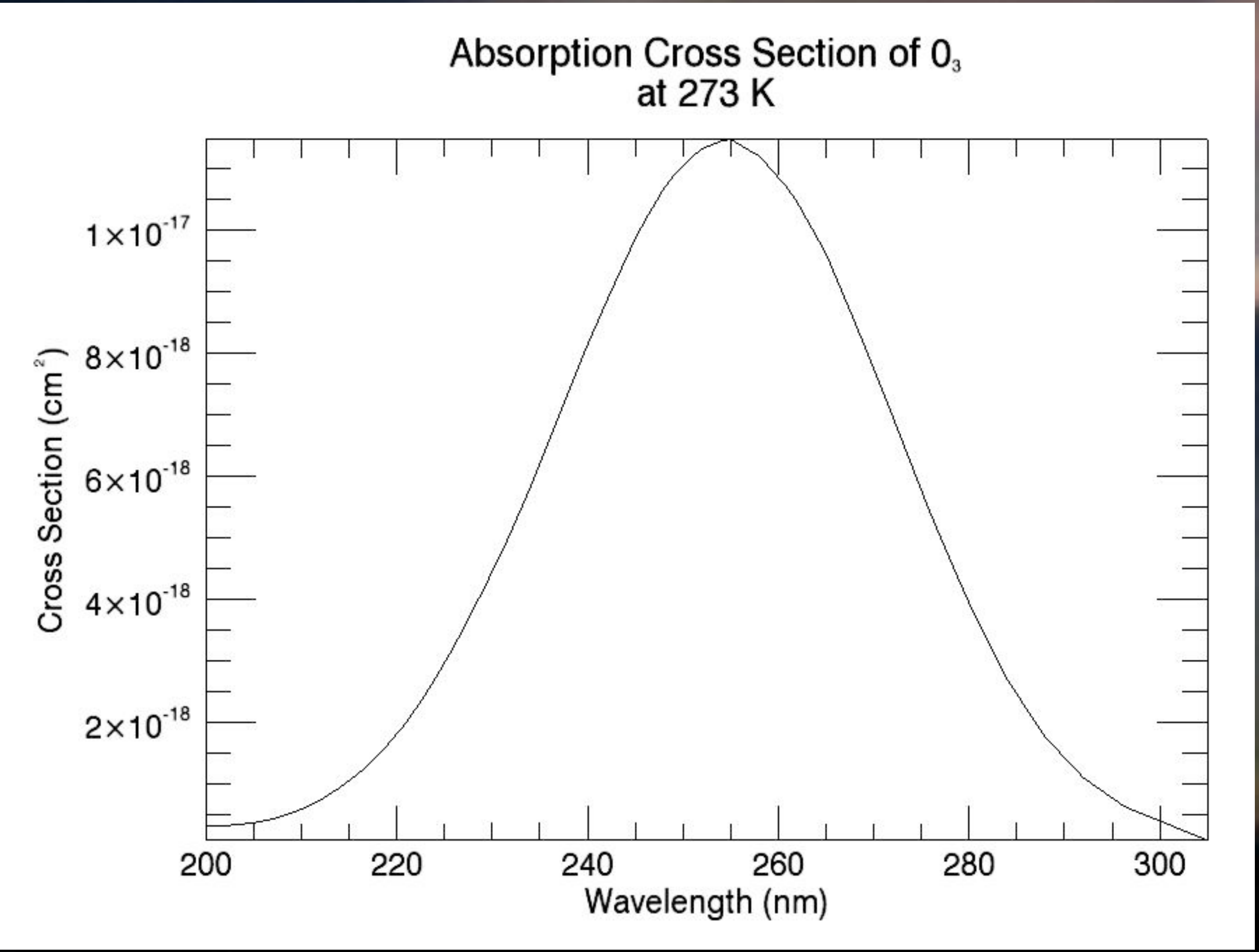

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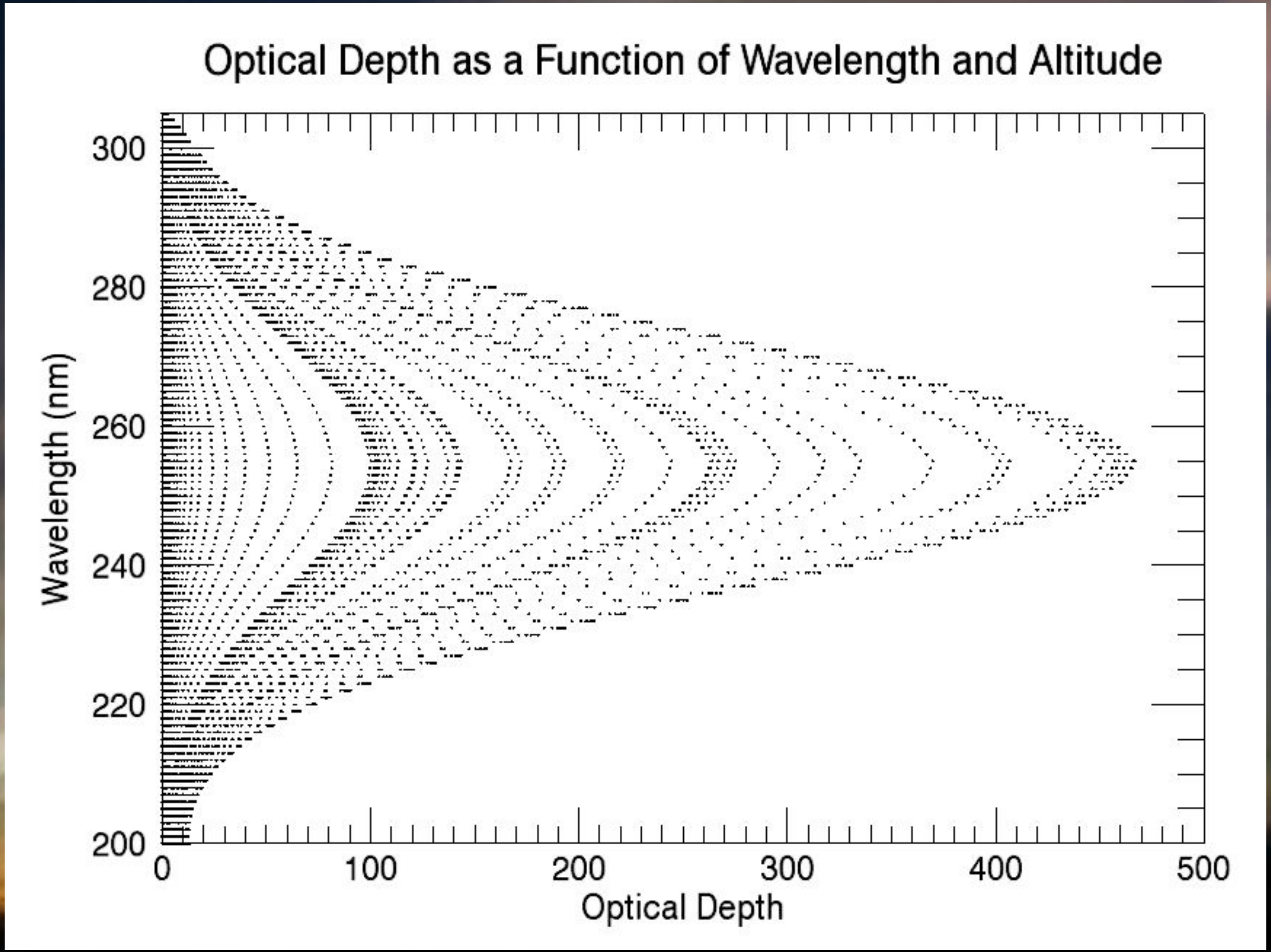

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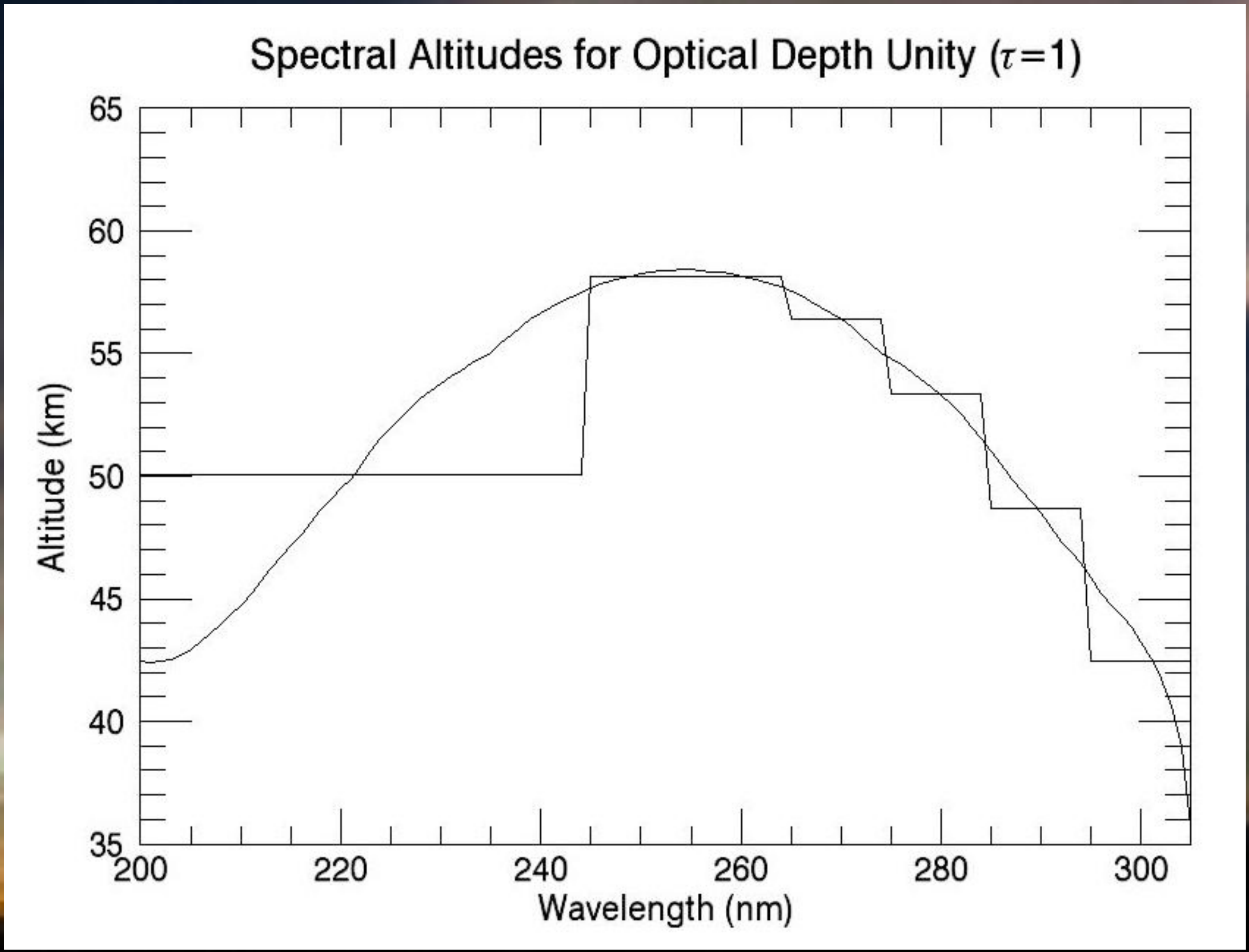

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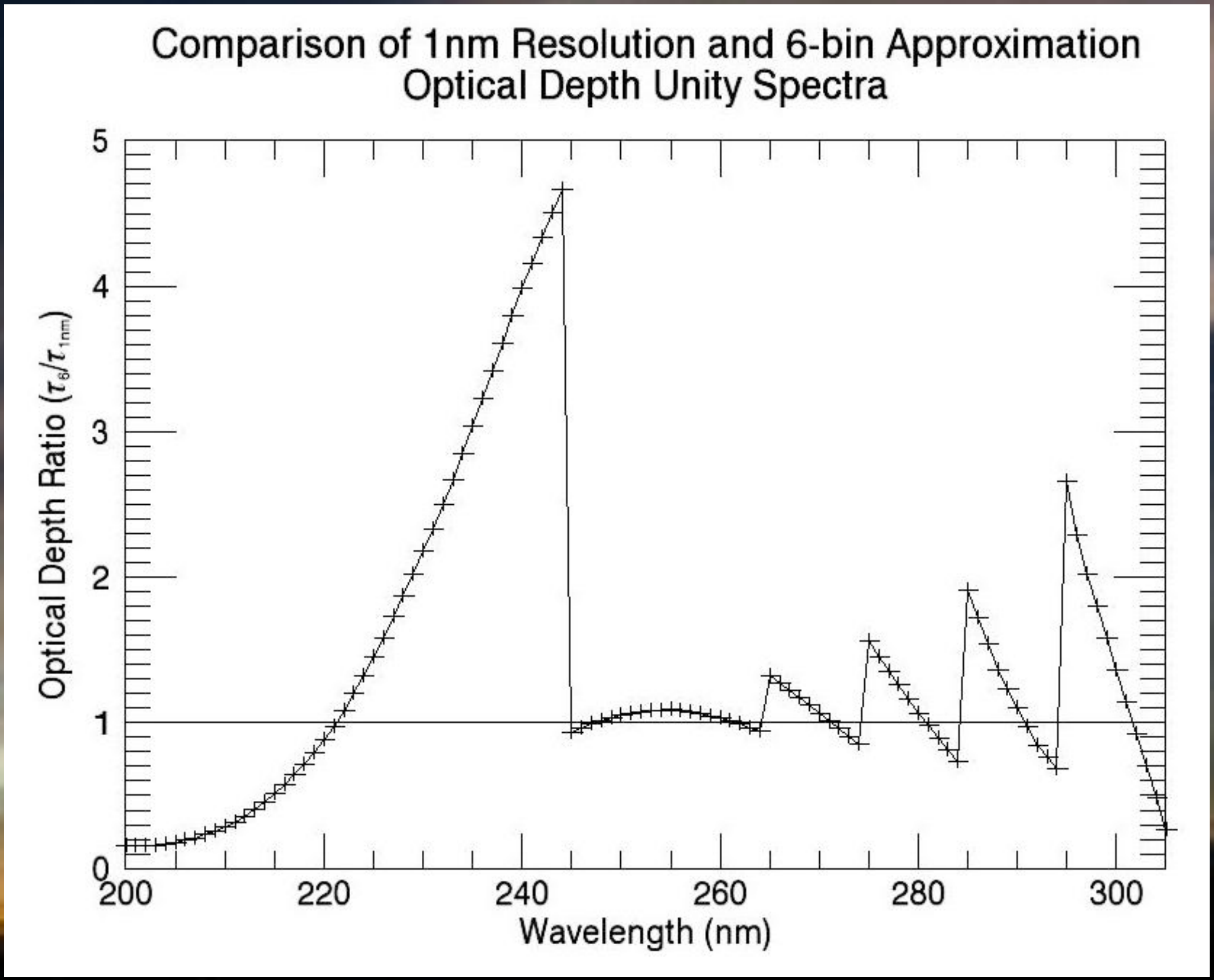

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# Solar Energy Penetration

- The Beer-Lambert Law
  - Relates pre- and post-absorption irradiances and the optical depth of the medium by:

$$I = I_0 e^{-\tau}$$

- Solar irradiance values obtained from SORCE used as the values at 120 km
- Irradiance at each decreasing altitude value was then calculated
- The same was done using the bin-averaged irradiance values
  - all wavelengths in a bin have the same irradiance
- Irradiance values were integrated over wavelength for each altitude in both cases

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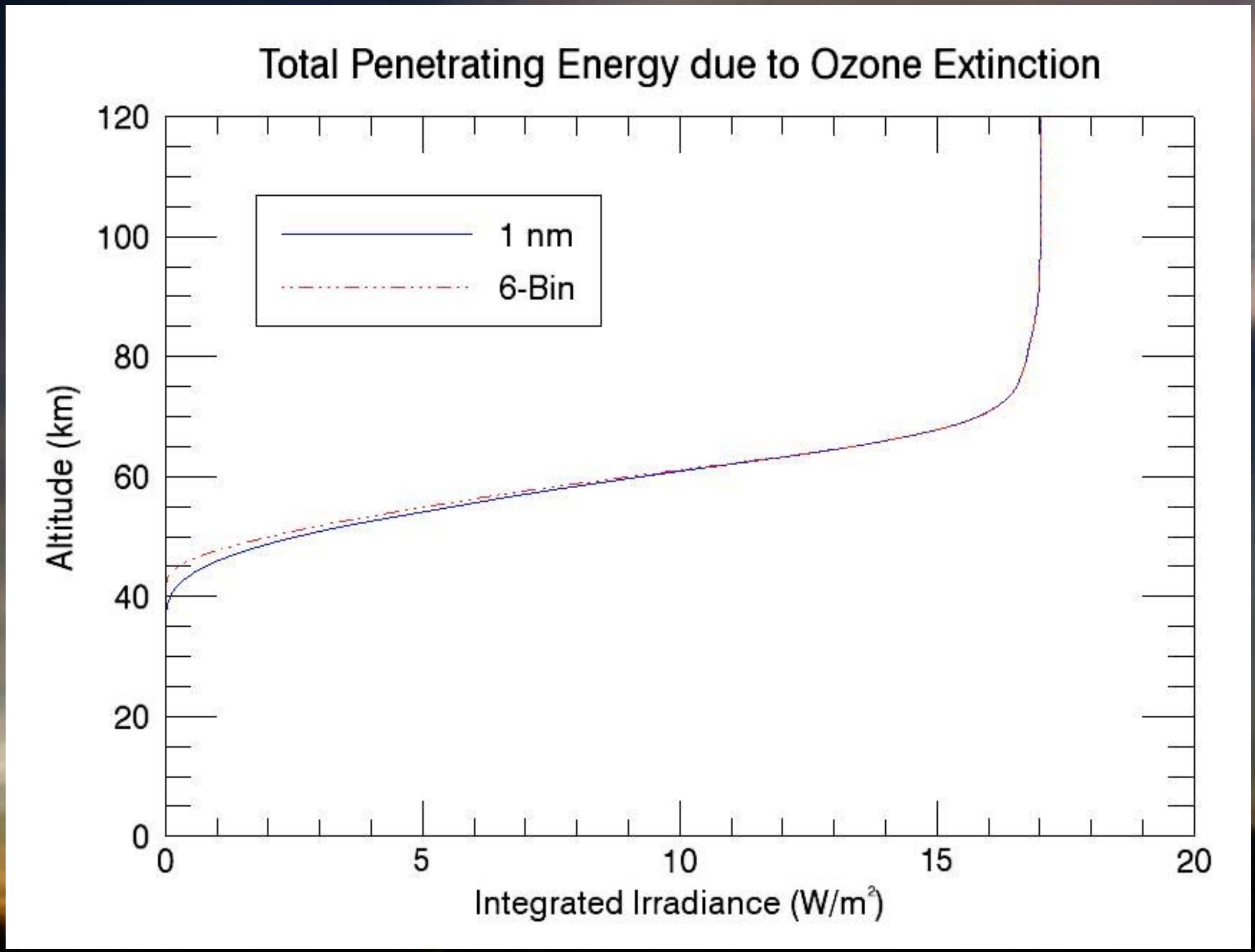

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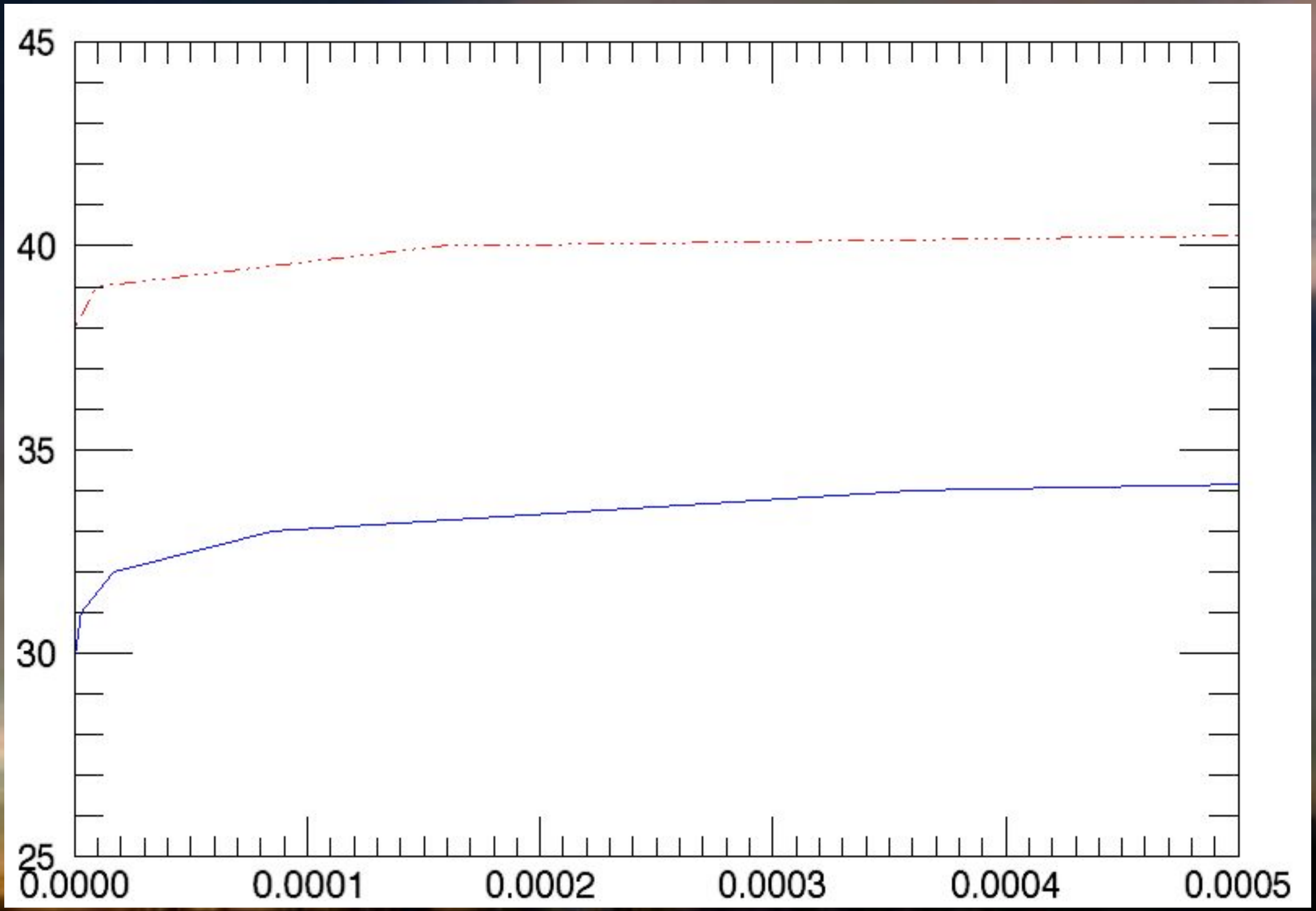

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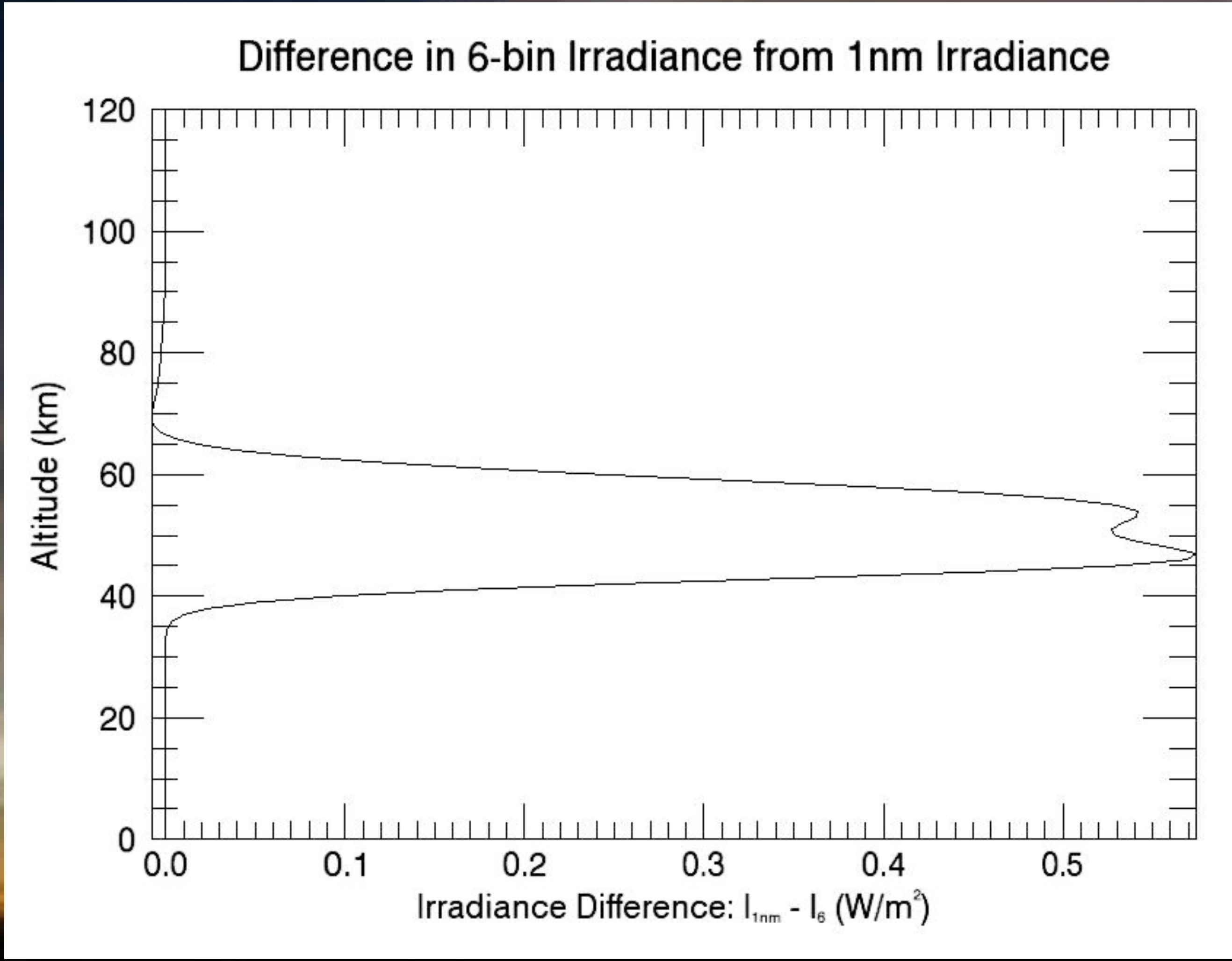

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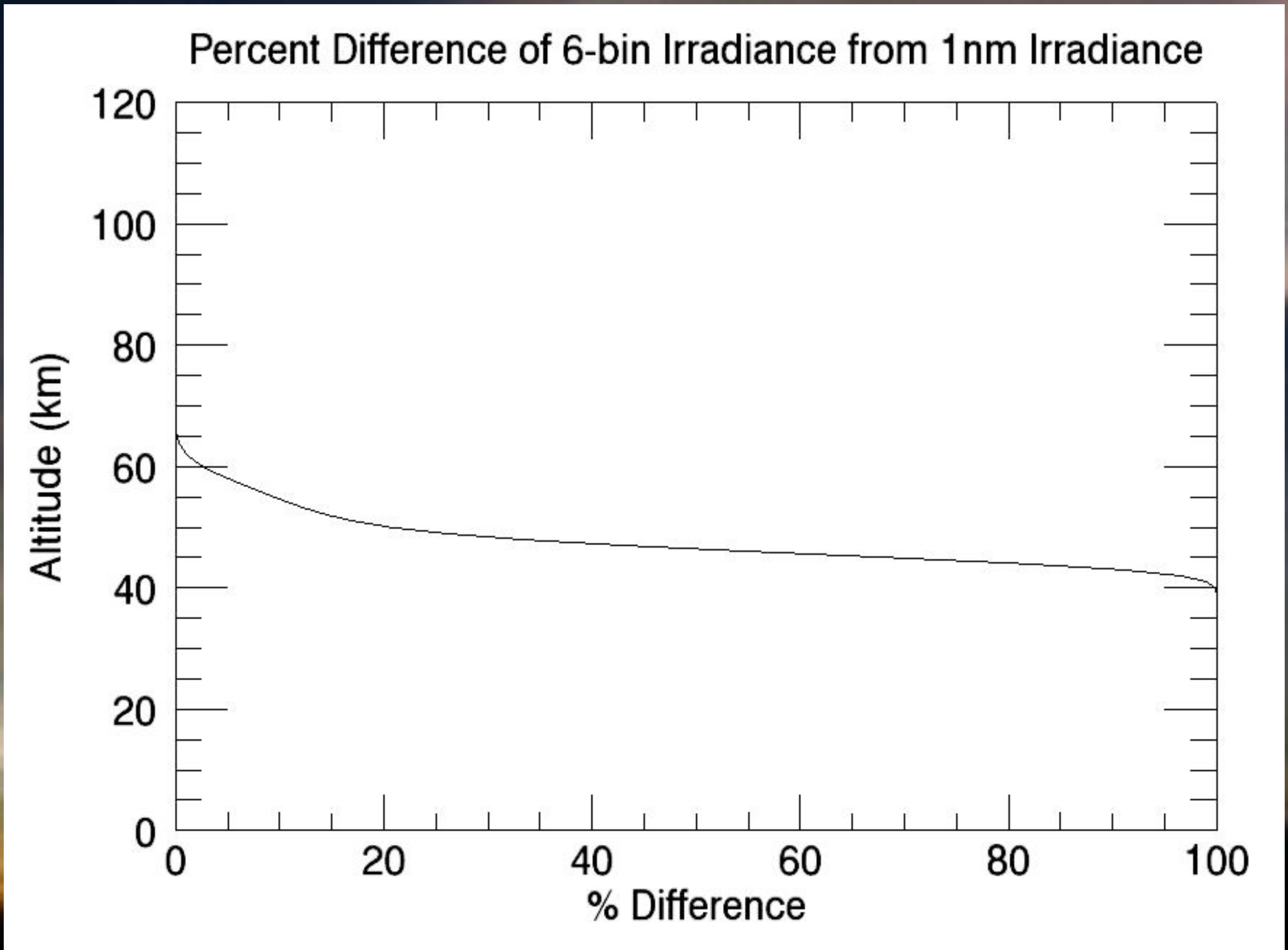

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# Results and Conclusions

- The optical depth at small wavelengths of the 6-bin approximation is almost 5 times that of the 1 nm model
- The extinction altitude of the 1 nm resolution spectrum is approximately 29 km
- The extinction altitude of the 6 bin spectrum is approximately 38 km
- The difference in altitudes results in a maximum irradiance difference of almost 0.6 $W/m^2$ at 47 km
- The 6-bin model approaches 100% difference from the 1 nm resolution model at 40 km
- By employing wavelength binning, solar irradiance energy is deposited higher in the atmosphere that should be expected

# Future Research

- Expand to a plane-parallel atmospheric model
  - Includes scattering of the solar photons (not just absorption)
- Include more atomic and molecular species to get a more realistic simulation of the atmosphere
- Do the same analysis for different atmospheric conditions (seasonal and regional) to see if there is a change in result

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# References

[1] "Atmospheric Browser." SpectralCalc.com. GATS Inc. 16 July 2007 <http://www.spectralcalc.com/spectralcalc.php>.

[2] Briegleb, Bruce P. "Delta-Eddington Approximation for Solar Radiation in the NCAR Community Climate Model". Journal of Geophysical Research, Vol. 97, Pg: 7603-7612. May 20, 1992.

[3] "Chemical Kinetics and Photochemical Data for Use in Stratospheric Modeling". JPL Publication 94-26, Evaluation Number 11, Pg: 114-116. Nov. 15, 1994.

[4] Rybicki, George B. and Lightman, Alan P. Radiative Processes in Astrophysics. New York: John Wiley & Sons, Inc., 1979.

[5] "Spectra Measurements" LASP Interactive Solar Irradiance Datacenter. LASP, University of Colorado. 16 July 2007 <http://lasp.colorado.edu/cgi-bin/ion-p?page=lisird_spectra_input.ion>.

• With thanks to Marty Snow and Erik Richard

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# Questions