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The tasks of this work consisted of (a) Upgrading the PL/GP diurnal photochemical code to include the Schumann-Runge continuum to produce the $O(^1D)$, and examine the role $O(^1D)$ plays in the CO_2 4.3 μm radiance. (b) Improving the SHARC high altitude atmospheric generator especially around the terminator to produce very good agreement with the CIRRIS-1A measurements.

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Optimization of atmospheric radiance algorithms for remote sensing:

Improvements in minor species photochemical code and its impact on IR radiances.

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24 May 1994

1. Introduction:

This is a summary report of the work done by Stewart Radiance Laboratory (SDL) during FY93 under the SERDP program for optimization of atmospheric radiance algorithms for remote sensing. The tasks consisted of (a) Upgrading the PL/GP diurnal photochemical code to include the Schumann-Runge continuum to produce the $O(^1D)$, and examine the role $O(^1D)$ plays in the CO_2 4.3 μm radiance. (b) Improving the SHARC high altitude atmospheric generator especially around the terminator to produce very good agreement with the CIRRIS-1A measurements.

2. Upgrade the PL/GP photochemistry code to study non-LTE effects on CO_2 4.3 μm:

An existing PL/GP one dimensional Diurnal Photochemical Code (DPC), which is currently used to generate self consistent minor species profiles for a specified latitude, day of the year and time of day, was improved. The chemical reaction rates in the DPC were updated from the latest *Jet Propulsion Laboratory* [1990] compilation, supplemented by rates from the recent literature, in addition to improvements in the transport processes in the code, parametrized by vertical eddy diffusion coefficients *Makhlouf et al* [1994]. The Schumann-Runge continuum which is an important UV source in photo-dissociating the molecular oxygen O_2 was missing in the DPC. This Schumann-Runge continuum source was added to the code due to its importance in producing the atomic oxygen excited state $O(^1D)$.

$$O_2 + h\nu \rightarrow O(^3P) + O(^1D) \qquad (133\text{nm} < \lambda < 175\text{nm})$$

The other source of $O(^1D)$ is the dissociation of ozone O_3 in the Hartley band. The $O(^1D)$ profile is a very sensitive function to the solar zenith angle especially around twilight.

$O(^1D)$ plays a role in the 4.3 μm non-LTE enhancement of the CO_2 emission, since it is an important source of $N_2(v)$, which resonates with the CO_2 v_3 states. In the middle atmosphere dissociation of O_3 provides a large source of $O(^1D)$ which is rapidly quenched - predominantly by N_2. About 25% of the $O(^1D)$ energy is transferred to N_2 vibrational energy. This process provides non-LTE daytime excitation in addition to the solar pumping of the 4.3 μm states, several runs from the DPC were delivered to *Nebel et al 1994,* to be included in their 4.3 μm calculations. However, since the opacities for O_3 Hartley band dissociation and CO_2 v_3 solar excitation are sufficiently different, inclusion of the $O(^1D)$ source initiates earlier at sunrise, provides a large enhancement, as documented in the twilight SISSI rocket data, Figure (1). The inclusion of the $O(^1D)$ as a source of $N_2(v)$ improved the agreement between ARC/AARC models *[Winick et al*

1987] calculations and the measurements. This enhancement is predominantly in the (001) and (011) CO_2 states, *Winick et al* [1993].

3. Upgrades to the terminator SHARC atmospheric generator:

The updated DPC was used to improve the Air Force SHARC (Strategic High Altitude Radiance Code) Atmospheric Generator (SAG) especially around sunrise and sunset solar terminators. One of the most important effects for modeling calculations near the terminator is to account for the changes in the molecular number densities due to photochemical processes, along the line of sight (LOS).

Several runs were done using the DPC, for different solar zenith angles, in order account for the variability of the number densities, in this case the ozone, along the LOS. These runs were inputted into SHARC to calculate limb radiances along LOS in the 9.6 μm emission. Results were in very good agreement with the CIRRIS-1A data measurements, see Figure (2), which represents a great improvements over those calculations done using the SAG code. More of these results and comparisons will be presented and discussed during the 17th Annual Review Conference on Atmospheric Transmission Models at Hanscom AFB, Massachusetts during the second week in June (7-8 June 1994). Adopting the improved DPC as an atmospheric generator for SHARC yields a significant improvement for SHARC calculations over the currently used SAG. This model can be adapted to run in parallel with SHARC.

Continuing work to move into a two dimensional modeling that includes a meridional transport which plays an important role in determining the profiles of important atmospheric constituents such as the ozone and nitric oxides.

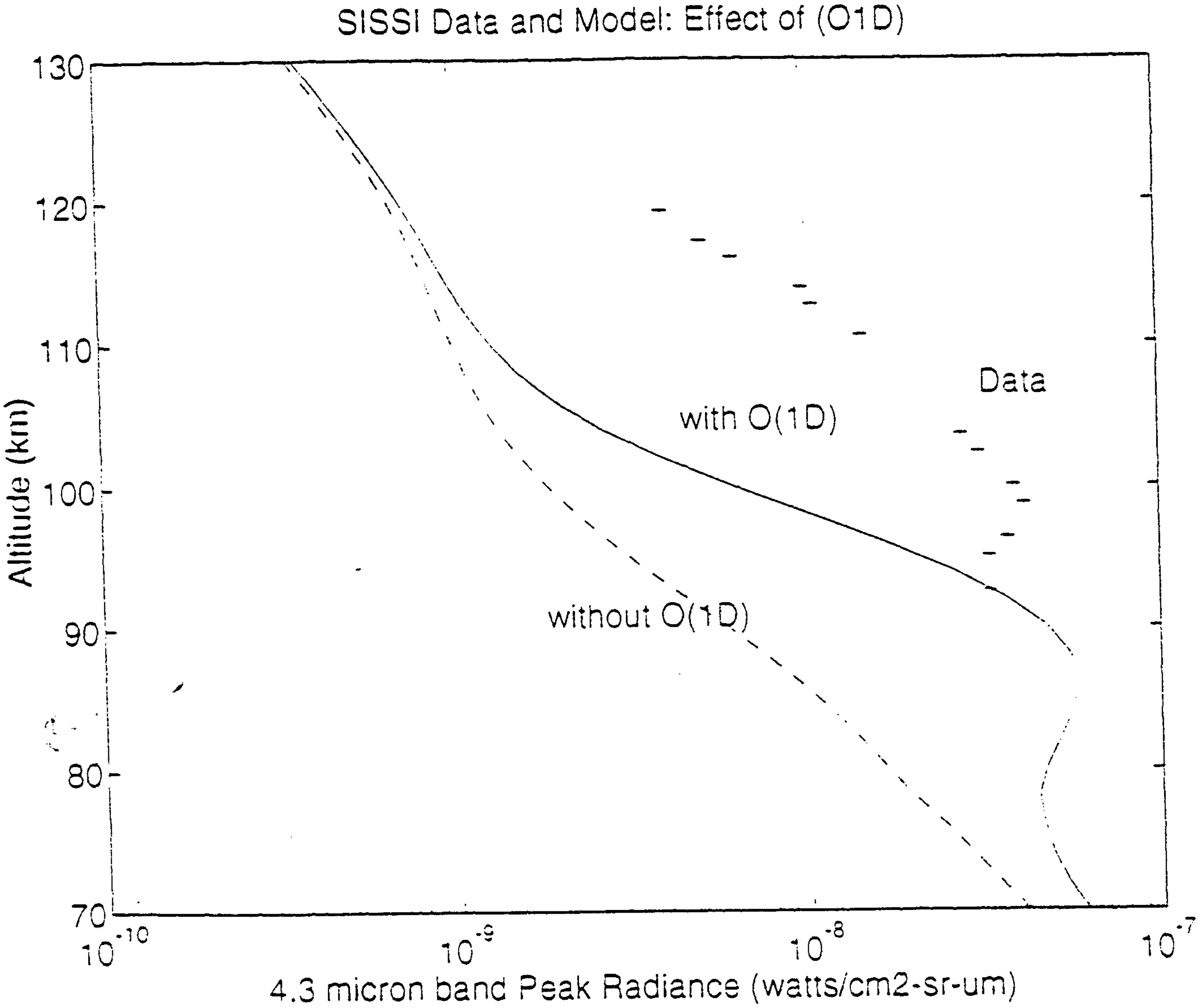

Figure 1 : 4.3 μm band radiance calculated with and without the O(^{1}D) source.

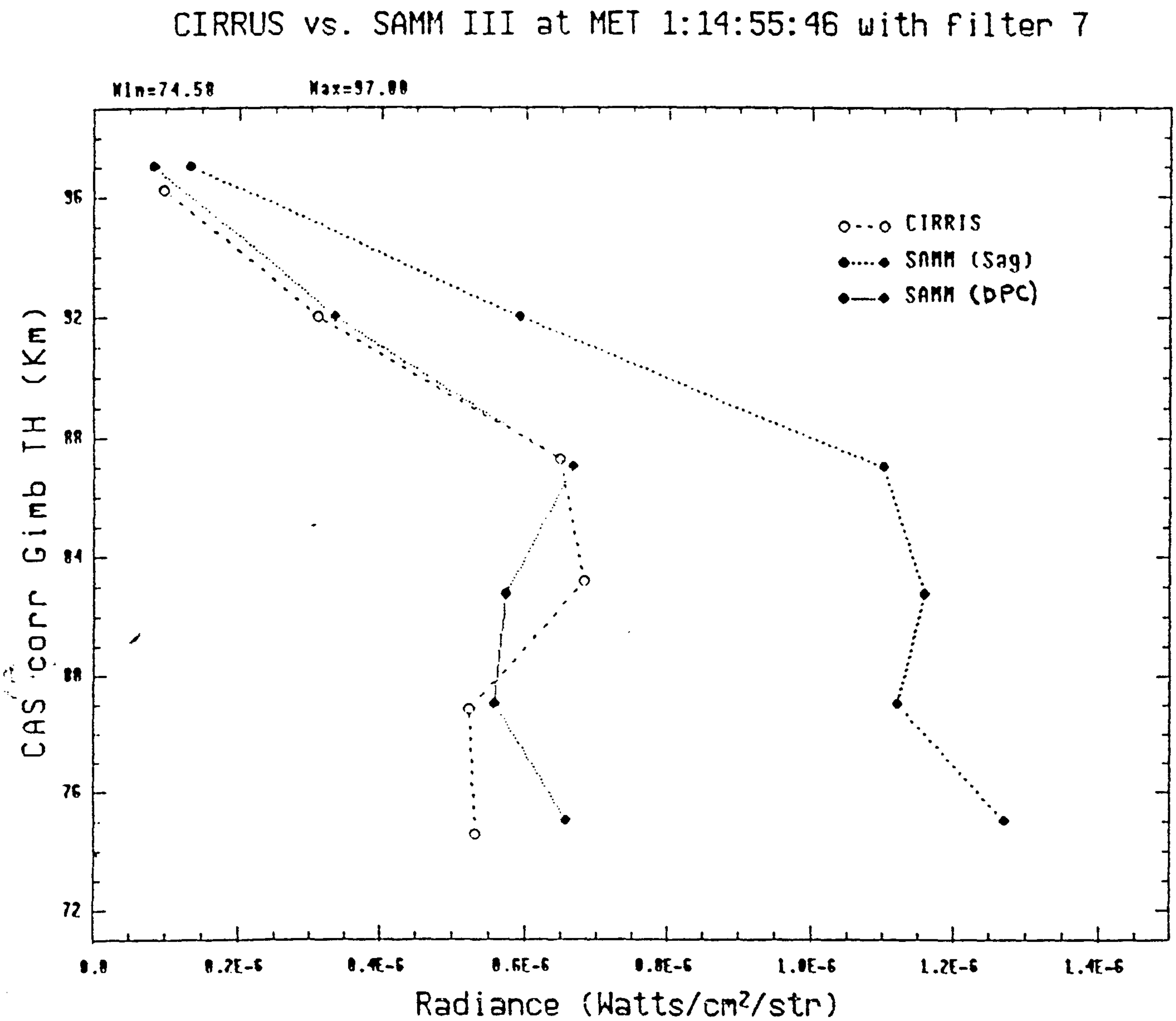

Figure 2 : 9.6 μm band radiance calculated using SHARC code using (a) the SHARC atmospheric generator (SAG), and (b) Diurnal Photochemical Code (DPC)

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