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VISIBLE AIRGLOW EXPERIMENT DATA ANALYSIS:

FINAL REPORT

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VISIBLE AIRGLOW EXPERIMENT DATA ANALYSIS
NASA GRANT (NAGW-496): FINAL REPORT

The Visible Airglow Experiment (VAE) was designed to provide detailed profiles of the distribution of excited states of atoms and molecules in the upper atmosphere. The studies supported during the funding period (1983 - 1989) have made significant contributions in the area of thermospheric aeronomy, and the progress during the first four years of this period has been reviewed by **Hays et al. [1988]**. The investigations carried out have resulted in more than 20 publications, and these are summarized below.

1. INVERSIONS

The technique of determining the local emission rate or density of an excited species observed with the VAE instrument involves the inversion of line of sight brightness measurements. Early techniques relied on the assumption that the airglow did not vary in the horizontal direction. Considerable effort has therefore been directed at the development of improved two-dimensional generalized inversions which are capable of interpreting VAE measurements even in highly structured situations, such as occur in the aurora. The tomographic inversion technique **[Solomon et al., 1984, 1985; Abreu et al., 1989]** has proven highly successful in the recovery of auoral 6300 Å, 5577 Å, 3371 Å and 4278 Å emission features **[Solomon, 1987; Solomon et al., 1988]**.

2. THE 6300 Å EMISSION

VAE studies of the atomic oxygen red line emission at 6300 Å, which arises from the ^3P - ^1D transition, have been of crucial importance in determining the thermospheric chemistry of the $O(^1D)$ metastable species. The suggestion by **Yee et al. [1985a]** that the quenching of $O(^1D)$ by $O(^3P)$ atoms was significant in the thermosphere was followed by a reanalysis of VAE 6300 Å nightglow data in order to determine the quenching rate coefficients for O and N_2

[Abreu et al., 1986]. The results of this work were utilized in a comprehensive examination of the production and loss mechanisms for O(^{1}D) in the nighttime auroral thermosphere **[Solomon, 1987; Solomon et al., 1988]**. In addition, these studies were extended to the 6300 Å dayglow **[Solomon and Abreu, 1989]**. In a theoretical investigation, **Yee et al. [1990]** obtained a rate coefficient for the quenching of O(^{1}D) by O(^{3}P) atoms which was consistent with the empirical value inferred from VAE data.

VAE observations of the 6300 Å nightglow have been employed in an investigation of low latitude neutral winds **[Burrage et al., 1990]**. This work demonstrated that visible airglow data is not only useful in the field of atmospheric chemistry, but may also be appliedto studies of global transport effects. Another topic pertaining to transport effects is the question of O(1D) thermalization in the nightglow. The determination of thermospheric neutral temperatures from observed 6300 Å line widths assumes that O(^{1}D) atoms are completely thermalized. The validity of this assumption has been tested by calculating the elastic and excitation exchange cross-sections in collisions of O(^{1}D) and O(^{3}P) atoms, which determine the degree of thermalization of the O(^{1}D) atoms produced by dissociative recombination **[Yee and Dalgarno, 1987; Yee, 1988]**.

3. THE 5577 Å EMISSION

The metastable transition between excited ^{1}S and ^{1}D states of atomic oxygen results in the atmospheric green line emission at 5577 Å. VAE measurements were used to generate a morphological map of the mesospheric 5577 Å emission, in which diurnal variations and shorter time scale variations due to travelling waves were observed **[Yee and Abreu, 1987]**. In addition, a study of the nighttime 6300 Å/5577 Å equatorial thermospheric emission ratio, as measured by the AE-E VAE, has facilitated the determination of the quantum yields of O(^{1}S) and O(^{1}D) from the dissociative recombination of O_2^+ **[Yee et al., 1989]**. A more recent study **[Yee and Abreu, 1990]** revealed situations near the equator in which the nighttime volume emission rate ratio η(6300Å)/η(5577Å) is enhanced during magnetically disturbed conditions, and a comparison with simultaneous measurements of the electron and atomic oxygen densities suggest that during magnetic storms the increase in low latitude atomic oxygen density due to high latitude heating causes a change in the vibrational distribution of O_2^+. This leads to a reduction in the quantum yield of $O(^1S)$ per dissociative recombination of O_2^+, and hence a decrease in the 5577 Å emission strength.

4. SPACECRAFT ENVIRONMENT INTERACTIONS

VAE photometric data were used in investigations of the optical glow induced by spacecraft-environment interaction, and these set the foundation for understanding the optical glow observed on the space shuttle. **Yee et al. [1984]** found that at altitudes above 160 km the VAE measured glow intensity was proportional to the ambient atomic oxygen density. A later study, which extended the analysis to lower altitudes, indicated that below 160 km the intensity of the emission was proportional to the product of the densities of any of N_2, O_2 or NO **[Yee et al., 1985b]**. In addition, spectrometric data from the Fabry-Perot interferometer on board the DE-2 satellite suggested that OH might be one of the species responsible for the vehicle interaction glow at 7320 Å **[Abreu et al., 1985]**.

5. OTHER STUDIES

An important goal of auroral studies is to infer the energy inputs to the high latitude thermosphere from remote observations. The capability of the VAE instrument for studying the ionospheric response to auroral energetic particle precipitation was first demonstrated by **Rees and Abreu [1984]** using VAE photometric measurements of the N_2^+ (1NG) 4278 Å band. **Solomon [1989]** employed the tomographic inversion technique to analyze VAE auroral observations made at 3371 Å, 4278 Å, and 6300 Å, and these were in reasonable agreement with predictions derived from theoretical calculations of the auroral secondary electron flux.

At low latitudes, **Abreu et al. [1984]** presented the first observations of the ultraviolet OI 989 Å emission in the nightglow, using the extreme ultraviolet spectrometer on board the STP 78-1 satellite. In addition, VAE 6563 Å data from the AE-E spacecraft were employed in a study of the tropical geocoronal H Balmer α nightglow **[Burrage et al., 1989]**. This investigation was undertaken to resolve a discrepancy between theory, ground based observations, and measurements made by the earlier D2A satellite. The diurnal and seasonal variation of the equatorial nighttime mesospheric hydroxyl emission (8-3 band) has been studied using VAE photometric observations at 7320 Å obtained from AE-E **[Abreu and Yee, 1989]**. Morphological maps of the hydroxyl zenith intensities as a function of latitude and local time were generated for both solstice and equinox conditions, and were found to be in good agreement with ground based measurements and theoretical simulations.

Finally, the experience gained in studies of upper atmospheric chemistry has in one instance been applied to an astrophysical problem. **Yee et al. [1987]** derived the equilibrium energy distribution of energetic N^+ ions in cold interstellar clouds and calculated the effective reaction rate coefficients.

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