NASA-CR-202533

The Annual Progress Report for Contract NAGW-5021
"Study of Venus Neutral Upper Atmosphere Using Magellan Drag Measurements"

N. Christina Hsu and J. Lyu
Hughes STX, Greenbelt, Maryland

Gerald M. Keating and Robert H. Tolson
George Washington University, Hampton, Virginia

Steve W. Bougher
University of Arizona, Tucson, Arizona

This annual progress report summarizes the major accomplishments made in the first year of this study. During this time period, we have adjusted the Magellan atmospheric drag measurements to account for the changes in the spacecraft cross section with time. Also the models of the Venus neutral upper atmosphere structure and composition given in the Venus International Reference Atmosphere (VIRA) (Keating et al., 1985) have been substantially improved by taking into account the Magellan atmospheric drag data over the period 1992-1994, and the final Pioneer Venus data from 1992 (Keating et al, 1995, 1996a, and 1996b), and atomic hydrogen drag effects.

The previous model, symmetric before and after noon, was based on Pioneer Venus data obtained only during high solar activity (1979-80). The new model is asymmetric with respect to noon and uses boundary conditions at 150 km, based largely on mass spectrometer data, and temperature distribution determined from the atmospheric drag data (between 130 and 220 km). Altogether 20 unknowns are solved for in the differential correction program using the combined Magellan and Pioneer Venus data sets which cover high (F10=200) to low (F10=80) solar activity. Thus, the new model establishes how the Venus thermosphere varies over the 11-year solar cycle.

We found that over the solar cycle exospheric temperatures on the dayside only vary about 70° K as shown in Figure 1. Variations of temperature with solar activity on the nightside have been isolated and are small (~10°K) but larger than predicted by earlier models. Temperatures are higher near the evening terminator than the morning terminator, as indicated in the third quarterly progress report. The first complete diurnal cycle of atomic oxygen made during the lower solar activity period was obtained from the Magellan Cycle 4 data, as shown in the third quarterly progress report. The effect of the 11-year solar cycle on the variations of the Venus thermospheric composition on the dayside and nightside has been clearly demonstrated by the direct comparison of in situ atomic oxygen measurements obtained from both the earlier PVO mission (high solar activity) and the Magellan mission (low solar activity) in the second quarterly progress report. Part of the density change on the nightside with increasing solar activity appears to come from increased production of atomic oxygen (O) on the dayside with consequent transport to the nightside.

Recent measurements were obtained in the CO2 regime during Magellan aerobraking as well as during the final phases of the Magellan and Pioneer Venus missions. It was found that CO2 near 140 km increased with decreasing solar activity. On the other hand, atomic oxygen was found to increase with solar activity more strongly than expected, perhaps due to increased atomic oxygen production. These two compositional effects balance one another near 160 km where there is little variation of total densities over the solar cycle (see Figure 2).

The cause of the cool thermosphere and the weak thermal response to both the 11-year and 27-day solar variations has been attributed to very strong thermal emission of CO2 brought about principally by atomic oxygen exciting the bending mode of CO2 into strong 15 micron emission (Keating and Bougher, 1992; Keating and Hsu, 1993). If the O/CO2 ratio increases, this cooling mechanism becomes even more effective. The new VIRA models show a very strong increase of the O/CO2 ratio with increasing solar activity. Recent complementary theoretical studies by Steve Bougher of the University of Arizona also show increases in the O/CO2 ratio with increasing solar activity. Thus the Venus atmosphere acts as a natural thermostat increasing its cooling when solar activity increases.

In addition, with high altitude drag measurements on the nightside at low solar activity (1994), we have now isolated helium and hydrogen drag effects for the first time. Shown in Figure 3 is the diurnal variation of composition at 200 km near solar minimum given in our new empirical model. Helium and atomic hydrogen are seen to be the principal nightside species at 200 km generating the drag effect. Measurements in the helium drag regime show no significant increase in the helium bulge at low solar activity, contrary to the prediction in the Hedin et al. (1983) model. Measurements in the higher altitude atomic hydrogen regime (above 200 km) during Magellan Cycle 6 (1994) are not inconsistent with the atomic hydrogen estimates from charge exchange obtained by Brinton et al. (1980). The mass spectrometer sensitivities of CO2, O, and He derived by Hedin et al. (1983) are consistent within 20% with the mean sensitivities of these species derived from drag measurements.

Other contributions during 1995-96 include publishing the book Exploration of Venus and Mars Atmospheres edited by G. M. Keating (Keating, 1995), and contributing to the Venus II book (Kasprzak et al., 1996).

The updated VIRA model is limited to equatorial measurements between ±20° latitude. In the year 2, we will expand the model to mid and high latitudes using Magellan orbital decay and drag torque measurements to study the latitudinal variations up to 80°N of the Venus thermospheric density, temperature, and composition.

Publications and Presentations made in the first year

Kasprzak, W. T., G. M. Keating, N. C. Hsu, A. I. F. Stewart, W. B. Colwell, and S. W. Bougher, Solar activity behavior of the thermosphere, Venus II, (in press), Univ. of Arizona Press, 1996.

Keating, G. M., (Editor), Exploration of Venus and Mars Atmospheres, 189 pages, Pergamon Press (Oxford), 1995.

Keating, G. M., N. C. Hsu, J. Lyu, and R. H. Tolson, Venus thermospheric response to solar cycle variations, Proceedings of 27th annual meeting of the DPS of the AAS, Mauna Lani, Hawaii, 22, 1995.

Keating, G. M., N. C. Hsu, J. Lyu, and R. H. Tolson, Magellan thermospheric measurements of Venus, Annales Geophysicae, 14, supp. 3, c798, 1996a.

Keating, G. M., N. C. Hsu, and J. Lyu, Improved thermospheric model for the Venus International Reference Atmosphere, Adv. Space Res. (Approved for Publication), 1996b. (Presented at 31st Scientific Assembly of COSPAR, Birmingham, England, 1996b).

Other References

Brinton, H. C., et al., Venus nighttime hydrogen bulge, Geophys. Res. Lett., 7, 865-868, 1980.

Hedin, A. E., et al., Global empirical model of the Venus thermosphere, J. Geophys. Res., 88, 73-83, 1983.

Keating, G. M., and S. W. Bougher, Isolation of major Venus cooling mechanism and implications for Earth and Mars, J. Geophys. Res., 97, 4189-4197, 1992.

Keating, G. M., and N. C. Hsu, The Venus atmospheric response to solar cycle variations, Geophys. Res. Lett., 20, 2751-2754, 1993.

Keating, G. M., et al., Models of Venus neutral upper atmosphere: structure and composition, Adv. Space Res., 5(11), 117-171, 1985.

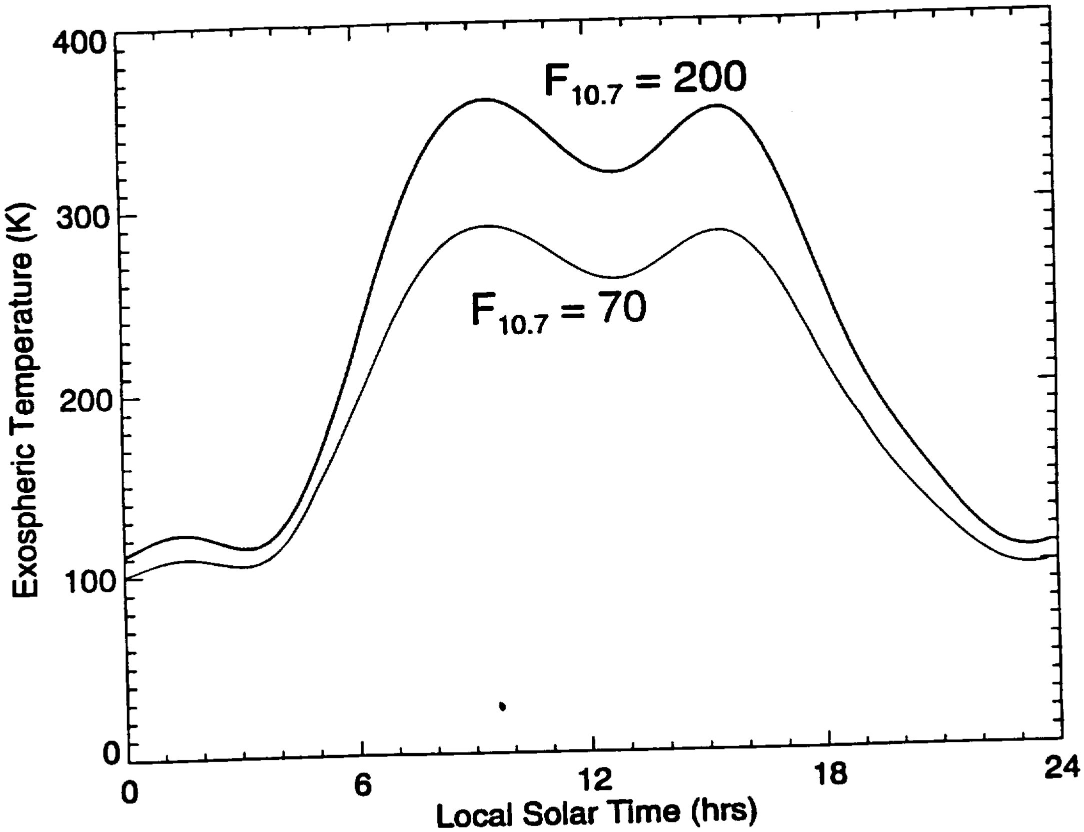

Figure 1 Diurnal variation of exospheric temperature from solar minimum to solar maximum.

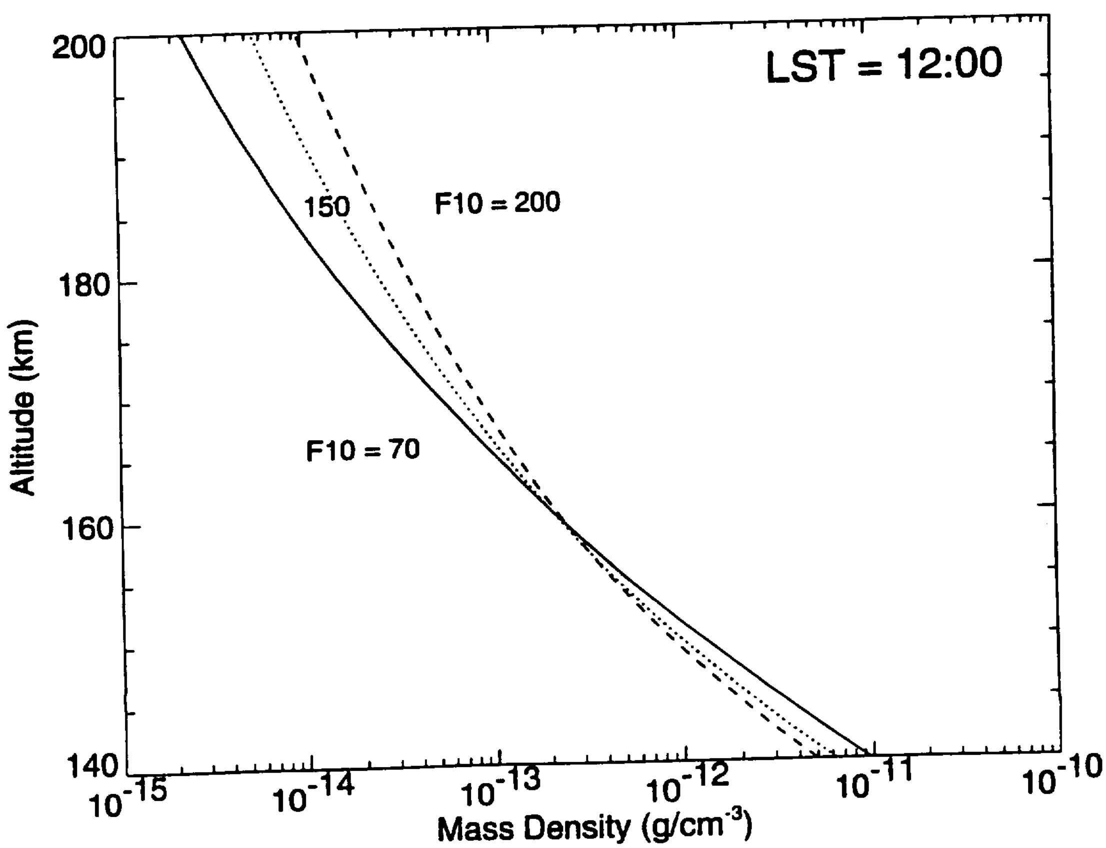

Figure 2 Atmospheric density variation over solar cycle (noon).

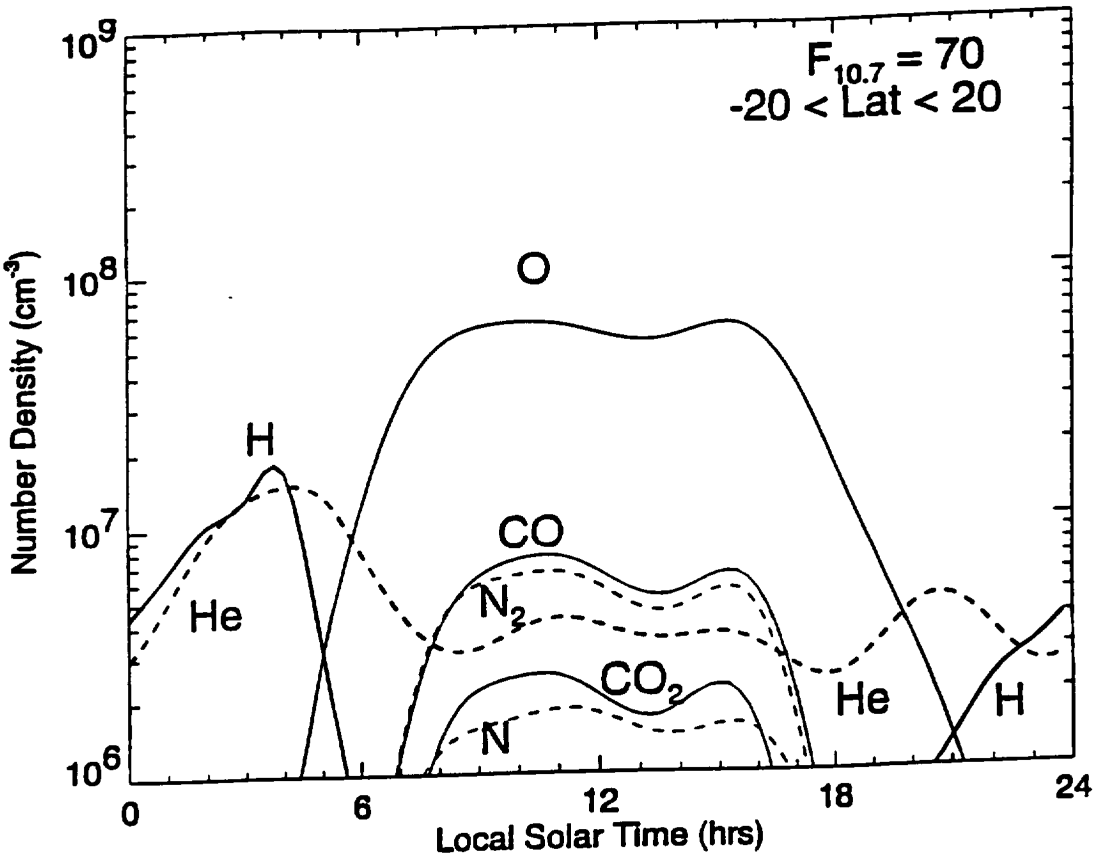

Figure 3 Diurnal variation of composition at 200 km near solar minimum.