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Reduction and Analysis of Seasons 15 and 16 (1991-1992) Pioneer Venus Radio Occultation Data and Correlative Studies with Observations of the Near Infra-Red Emission of Venus

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Submitted by

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I. Introduction

Radio occultation experiments, and radio astronomical observations have suggested that significant variations (both spatial and temporal) in the abundances of sulfur-bearing gases are occurring below the Venus cloud layers [Jenkins and Steffes, 1991]. In addition, recent Near Infra-Red images of the nightside of Venus revealed large-scale features which sustain their shape over multiple rotations (the rotation periods of the features are 6.0 $\pm$ 0.5 days [Crisp, et al., 1990]). Presumably, the contrast variations in the NIR images are caused by variations in the abundance of large particles in the cloud deck. If these particles are composed of liquid sulfuric acid, one would expect a strong anticorrelation between regions with a high abundance of sulfuric acid vapor, and regions where the large particles. One technique for monitoring the abundance and distribution of sulfuric acid vapor (H_2SO_4) at and below the main Venus cloud layer (altitudes below 50 km) is to measure the 13-cm wavelength opacity using Pioneer Venus Orbiter Radio Occultation Studies (PV-ORO) [Steffes, 1985].

In this study, we are working to characterize variations in the abundance and distribution of subcloud H_2SO_4(g) in the Venus atmosphere by using a number of 13-cm radio occultation measurements conducted with the Pioneer Venus Orbiter near the inferior conjunction of 1991. When retrieved, the vertical profiles of the abundance of H_2SO_4(g) will be compared and correlated with NIR images of the night side of Venus made during the same period of time. Hopefully, the combination of these two different types of data will make it possible to constrain or identify the composition of the large particles causing the features observed in the NIR images. Considered on their own, however, the parameters retrieved from the radio occultation experiments are valuable science products.

II. Summary of Activities

In the first half of this first year of Grant NCC 2-753 (April 1, 1992 through September 30, 1992) we have begun the work of acquiring 13-cm radio occultation data for reduction to obtain 13-cm absorptivity profiles. During this period, we have obtained occultation data sets from approximately ten experiments conducted in 1991, and have completed a preliminary analysis of four data sets from orbits 4661, 4663, 4668 and 4670 which occurred in September, 1991.

Table I gives a summary of various parameters of interest for these four experiments. Vertical absorptivity profiles for each of these experiments are shown in figure 1. These profiles were obtained by applying recently-developed signal processing techniques for analyzing data from radio occultation experiments [Jenkins, 1992]. Figure 2 shows vertical profiles of $H_2SO_4(g)$ mixing ratios for each of these experiments based on the absorptivity profiles in figure 1, and temperature and pressure profiles obtained by the Pioneer Venus sounding probe in 1979 [Seiff *et al.*, 1980]. The spatial coverage of these experiments is illustrated by figure 3, which shows the tracks of the deepest point probed during these four experiments. The relative longitude is referenced to the sub-Earth longitude for orbit 4661, and assumes a 5.5 day rotation period for the altitudes probed by the occultations. (The region of the atmosphere probed during near-equatiorial occultations is at a longitude of nearly 90° from the sub-Earth point. Thus, experiments conducted on two consecutive orbits of Pioneer Venus will probe regions of the atmosphere separated by approximately 65° of longitude, assuming a 5.5 day rotation period for the atmosphere.)

Below 50 km (above a mean radius of 6052 km), the sulfuric acid vapor abundances displayed in the profiles for orbits 4661, 4663 and 4668 are greater than abundances in the profile for orbit 4670, which shows a marked drop in sulfuric acid vapor below this altitude. This suggests that the first three orbits may have probed a contiguous region of the atmosphere rich in $H_2SO_4(g)$, while 4670 probed a region depleted of sulfuric acid vapor below the main cloud layer. If the regions of the Venus atmosphere probed by orbits 4661, 4663 and 4668 are located in bright features in the NIR images made during this same period of time, and the atmospheric track of 4670 is contained in a dark NIR feature, this will be strong evidence that the particles responsible for the dark NIR features are composed of sulfuric acid. The NIR images, however, need additional processing before this comparison and correlation are made (Boris Ragent, personal communication).

III. Conclusion and Plans for Future Work

The four data sets analyzed to date suggest that there are significant longitudinal variations in the abundance and distribution of sulfuric acid vapor at near-equatorial latitudes in the Venus atmosphere. More work needs to be done before these variations are fully characterized. This will involve careful examinations of the data sets examined thus far to determine if the results can be extended to lower altitudes, which would make stronger conclusions possible. There is also a need to estimate error bars for all retrieved profiles. Although the techniques used to derive these profiles have been demonstrated to be far superior to previous processing techniques [Jenkins, 1992], the statistical significance of the results cannot be evaluated until the experimental uncertainties are estimated. We plan to estimate error bars using the standard propagation of errors [Brandt, 1963]. This task should be completed by the end of February, 1993.

Once all the data taken during the period of September 10 through September 24, 1991 has been analyzed, other data sets from occultation season 15 will be processed. This will provide a means to evaluate latitudinal as well as longitudinal variations in the abundance and distribution of sulfuric acid vapor below the main cloud layer in the Venus atmosphere.

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V. Key Figures

TABLE I: SEASON 15 DATA SUMMARY

Orbit Number	4661	4663	4668	4670
Day of Year	253	255	260	262
Date	9/10/91	9/12/92	9/17/92	9/19/92
Solar Zenith Angle	55°	52°	45°	45°
Relative Longitude	270° E	41° E	9° E	139° E
Latitudes	-5° S to -12° S	-6° S to -14° S	-7° S to -15° S	-6° S to -11° S
Lowest Altitude	47 km	47 km	43.5 km	46.6 km

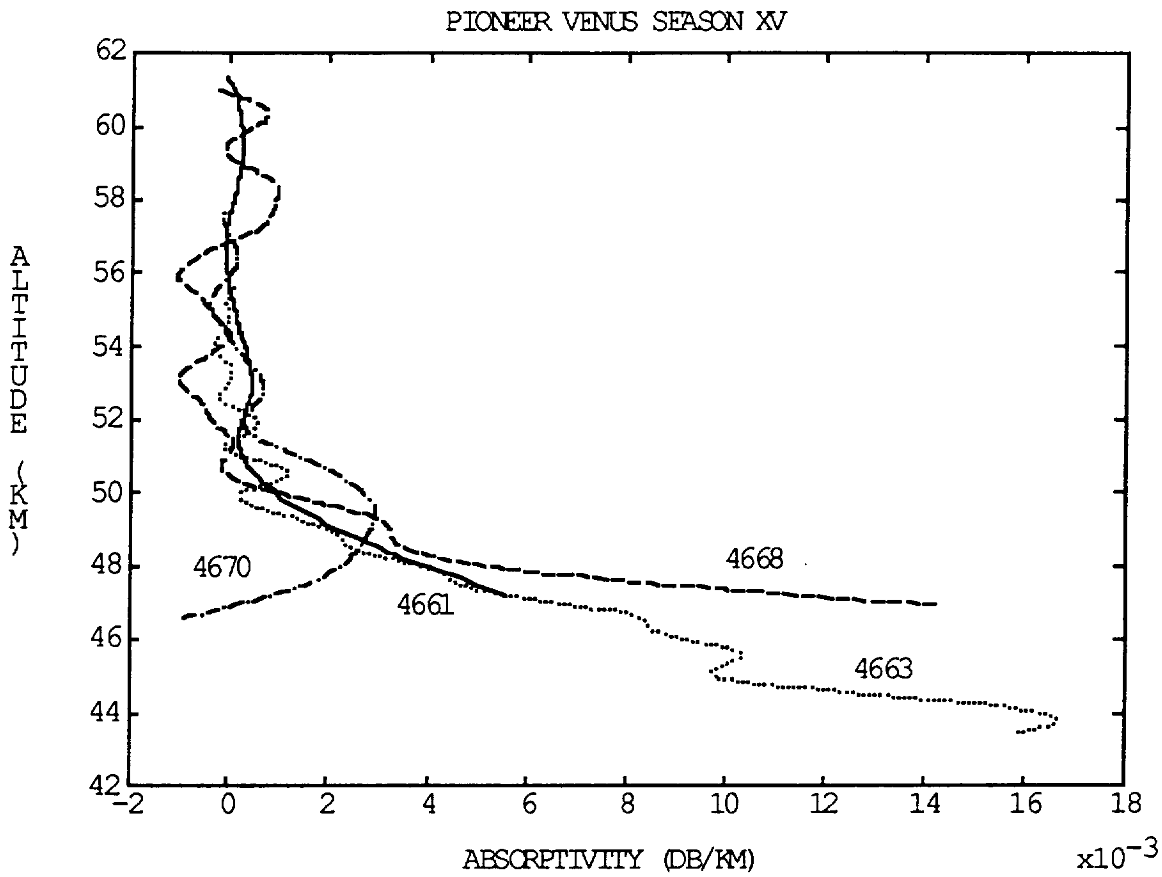

FIGURE 1: Absorptivity profiles retrieved from four radio occultation experiments conducted in September, 1991. There appears to be a depletion of sulfuric acid vapor in the near-equatorial region probed during orbit 4670.

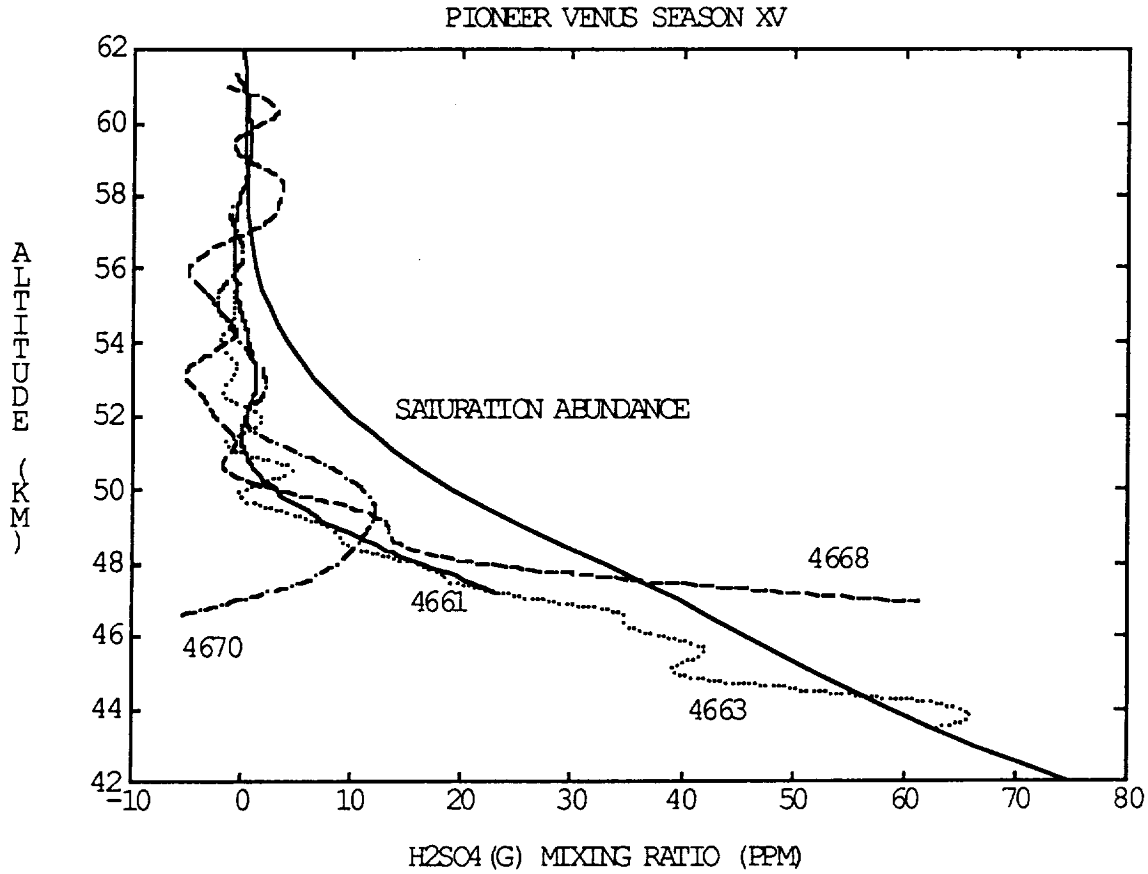

Figure 2: Abundance profiles for four radio occultation experiments conducted with the Pioneer Venus Orbiter in September, 1991. These profiles correspond to the absorptivity profiles in Figure 1.

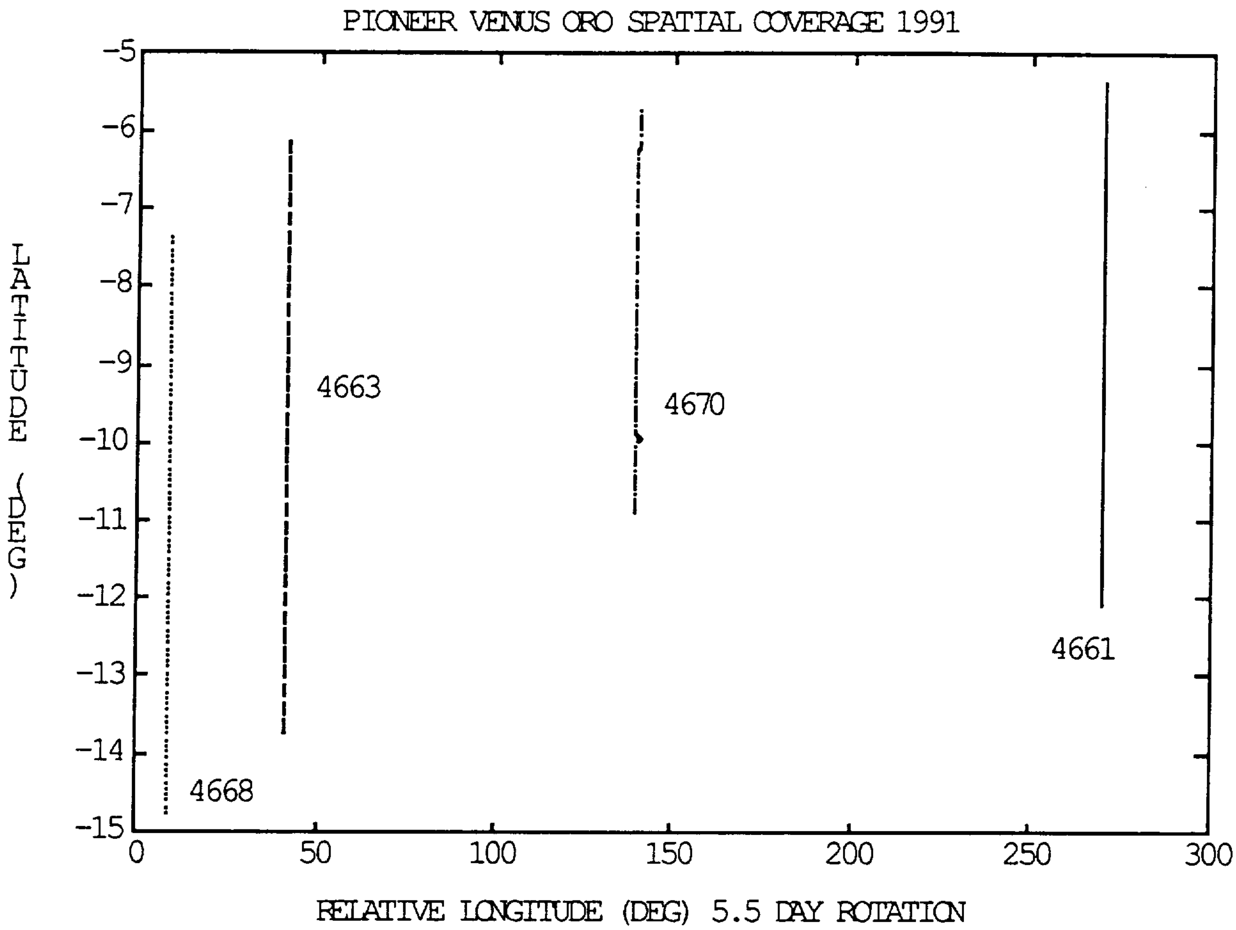

Figure 3: The portion of the Venus atmosphere probed by the radio signal from an occulted spacecraft changes during a radio occultation experiment. This figure shows the atmospheric tracks of occultation experiments below 60 km during orbits 4661, 4663, 4668 and 4670. The relative longitudes for each orbit were computed assuming a 5.5 day rotation period, and are referenced to the sub-earth longitude for the time of the experiment conducted on orbit 4661. Figures 1 and 2 suggest that 4661, 4663 and 4668 probed a contiguous region rich in sulfuric acid vapor, while 4670 probed a region depleted in sulfuric acid vapor.

VI. Attachments

Preliminary Correlation of Recent NIR Images of Venus with Pioneer Venus Orbiter Radio Occultation Studies

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Over the past few years, large-scale variations have been observed in near infrared (NIR) images of the nightside of Venus. These variations are due presumably to variations in the number density of large particles in the lower regions of the clouds[1,2]. If these particles are composed of sulfuric acid (H_2SO_4), the NIR opacity due to these particles would be expected to be anticorrelated with the 13-cm opacity due to sulfuric acid vapor in the same region of the atmosphere. ($H_2SO_4(g)$ is the dominant 13-cm absorber in the Venus atmosphere at altitudes near the base of the clouds.) To address this issue, a number of 13-cm radio occultation experiments were conducted with the Pioneer Venus Orbiter (PVORO) near the inferior conjunction of 1991. During the same time interval, we obtained near infrared (NIR) images of the night side of Venus. The quality of the PVORO data sets has been enhanced by the application of recently developed techniques for processing amplitude data from such experiments[3]. The new technique produces vertical profiles of 13-cm opacity with greater vertical resolution and smaller uncertainties than obtained previously. These data sets will be correlated to help constrain the composition of the large particles responsible for the variations in the NIR images.

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