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Venus Atmospheric Thermal Structure and Radiative Balance

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Abstract

Venus Express, observing since April 2006 has returned a wealth of useful information about the atmospheric temperature and density structure of the planet. New and refined instruments have advanced not only the accuracy but also the altitude range of the inferred structure. With multiple experiments on Venus Express contributing to the inferred vertical structure, there is overlap in some altitude regions, allowing and requiring conciliation of the inferred values in terms of spatial and temporal coverage as well as errors and biases. In addition, there are older spacecraft results as well as recent ground based observations that contribute to the new information about the thermal structure of the atmosphere. Regarding the radiative balance, we have new information about changes in the absorbed solar radiation over the duration of the Venus Express mission, but little new information in terms of the emitted radiation from the planet. A coordinated effort was initiated in late 2013 to assess these new data through an international team hosted by the International Space Studies Institute [1]. This solicited chapter for the Venus III book being developed at present [2] is based on the efforts of this group.

1. Introduction

A first synthesis of the thermal structure of the atmosphere between surface and 135 km altitude was published in 1983 [3] from the Pioneer Venus Orbiter (PVO) and Multi-Probe (PVMP) missions [4]. The orbiter experiments [5] that provided the results were the Orbiter Infrared Radiometer (PVOIR) and the Radio Occultation (PVRO) experiments. The results from the multi-probe mission came from the atmospheric structure experiment, the thermal sensors from the small probe net flux radiometer as well as decceleration of the probes and including data from the PVO and PVMP bus that also sampled the atmosphere at high altitudes [6]. Subsequently, a comprehensive model of the thermal structure was published [7] as part of the Venus International Reference Atmosphere [8] incorporating results from Venera 10, 12 and 13 landers, and later Zasova et al. published thermal structure update incorporating Venera 15/16 passive infrared results [9].

Two challenges were encountered in the developing the model [7] which are also relevant for the present effort and emphasize the need for intercomparison and reconciliation of the results from different experiments obtained at different times whether with some or little overlap in latitude and local time or longitude. The first challenge was the reconciliation of the data sets in the middle atmosphere where large differences (~ 10K) were frequently seen, between the in-situ measurements and the inferred values from passive infrared observations

2. Thermal Structure

The new thermal structure observations we consider in this effort include both active and passive remote sensing measurements from the Venus Express orbiter as well as the only new in-situ results from Venus Express [10]. The active measurements include a few high quality radio occultation profiles from Magellan [11] and a much larger number of profiles from Venus Express [12]and the first results about the thermal structure from solar [13] occultations from SOIR and stellar occultations from SPICAV at ultraviolet wavelengths [14]. The passive results are from the VIRTIS [15] experiment on board Venus Express and Venera 15/16 [9].

3. Radiative Balance

The radiative balance of the lower atmosphere was reviewed [16] and of the middle and upper atmosphere by [17]. Subsequently the radiative balance was reviewed for the entire planet just prior to Venus Express observations began [18]. Since then, few observations in the thermal infrared have been obtained. The visible imaging observations from the Venus Monitoring Camera [19] however

provides some new information about variations in the cloud properties, particularly albedo variations that are relevant for the planet's radiative balance.

4. Summary and Conclusions

The current state of knowledge of the thermal structure of Venus has been extended to a higher altitude level. Although a lot of new measurements have been obtained, there is still a problem of incomplete or non-uniform sampling in latitude, longitude and local time.

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