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DYNAMICAL CHARACTERISTICS OF THE VENUSIAN ATMOSPHERE: INSIGHTS FOR FUTURE IN SITU EXPLORATORY MISSIONS TO VENUS

Abstract

The Venusian atmosphere is highly dynamic, hosting some of the most extreme atmospheric phenomena in the solar system, including the zonal superrotation with high-speed winds hurling across the planet at the cloud tops, the gigantic meridional Hadley circulations, and the remarkable polar vortices. The planet is almost completely enshrouded by a thick deck of concentrated sulphuric acid clouds, with a notable middle-cloud unstable region of strong vertical mixing. The formidable atmospheric conditions, structure and dynamics of Venus make in situ exploration of the atmosphere challenging. Only a handful of descent probes and landers have previously dared to enter and transmit data from the Venusian atmosphere, and the majority of existing data comes from remote sensing measurements of the planet, albeit severely hindered by the cloud cover. The lack of in situ measurements from Venus is a major lacuna in our understanding of the planet's elusive atmosphere, warranting further exploration through atmospheric descent probes, aerial platforms and landers. The present study leverages a combination of state-of-the-art numerical models such as the LMD/IPSL Venus Planetary Climate Model (V-PCM) and satellite-based observational data from the Akatsuki and Venus Express missions to investigate Venusian atmospheric dynamics, providing insights on peculiar dynamical characteristics of the atmosphere which may potentially have an impact on the design and implementation of future in situ exploration missions. The modelled and observed datasets are used to study the thermal structure and wind fields of Venus, particularly examining the stability and turbulence of the atmosphere at different altitude-latitude regions, through the derivation of cyclostrophic winds, wind shears, static stability, Richardson number and Reynolds number. One of the key results here is the identification of a statically stable but dynamically unstable region in the equatorial middle atmosphere, arising from strong vertical wind shears above the superrotating jet. With regard to Venusian atmospheric entry modules, the dynamical characteristics studied in this work could potentially have a bearing on various mission-specific aspects such as entry/landing site selection, descent trajectories, aerodynamic forcings and additional mission requirements, providing valuable insights for future exploratory missions to Venus.