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Venus Express as precursor of the Venus Decade

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Venus appears to be an "alien" planet drastically and surprisingly different from the Earth. The early space missions revealed the world with remarkably hot, dense, cloudy, and very dynamic atmosphere filled with toxic species likely of volcanic origin. During more than 8 years of operations ESA's Venus Express spacecraft performed a global survey of the atmosphere and plasma environment of our near neighbour. The mission delivered comprehensive data on the temperature structure, the atmospheric composition, the cloud morphology, the atmospheric dynamics, the solar wind interaction and the escape processes. Vertical profiles of the atmospheric temperature showed strong latitudinal trend in the mesosphere and upper troposphere correlated with the changes in the cloud top structure and suggesting convective instability in the main cloud deck at 50-60 km. Observations revealed significant latitudinal variations and temporal changes in the global cloud top morphology, which modulate the solar energy deposited in the atmosphere. The cloud top altitude varies from ~72 km in the low and middle latitudes to ~64 km in the polar region, correlated with decrease of the aerosol scale height from 4 ± 1.6 km to 1.7 ± 2.4 km, marking vast polar depression. UV imaging showed for the first time the middle latitudes and polar regions in unprecedented detail. In particular, the eye of the Southern polar vortex was found to be a strongly variable feature with complex dynamics.

Solar occultation observations and deep atmosphere spectroscopy in spectral transparency "windows" mapped distribution of the major trace gases H_2O, SO_2, CO, COS and their variations above and below the clouds, revealing key features of the dynamical and chemical processes at work. A strong, an order of magnitude, increase in SO_2 cloud top abundance with subsequent return to the previous concentration was monitored by Venus Express specrometres. This phenomenon can be explained either by a mighty volcanic eruption or atmospheric dynamics.

Tracking of cloud features provided the most complete characterization of the mean atmospheric circulation as well as its variability. Low and middle latitudes show an almost constant with latitude zonal wind speed at the cloud tops and vertical wind shear of 2-3 m/s/km. Surprisingly the zonal wind speed was found to correlate with topography decreasing from 110±16 m/s above lowlands to 84±20 m/s at Aphrodite Terra suggesting decelerating effect of topographic highs. Towards the pole, the wind speed drops quickly and the apparent vertical shear vanishes. The meridional cloud top wind has poleward direction with the wind speed ranging from about 0 m/s at equator to about 15 m/s in the middle latitudes. A reverse equatorward flow was found about 20 km deeper in the middle cloud suggesting existence of a Hadley cell or action of thermal tides at the cloud level. Comparison of the thermal wind field derived from temperature sounding to the cloud-tracked winds confirms the validity of cyclostrophic balance, at least in the latitude range from 30S to 70S. The observations are supported by the General Circulation Models.

Venus Express detected and mapped non-LTE infrared emissions in the lines of O_2, NO, CO_2, OH originating near the mesopause at 95-105 km. The data show that the peak intensity occurs in average close to the anti-solar point for O_2 emission, which is consistent with current models of the thermospheric circulation. For almost complete solar cycle the Venus Express instruments continuously monitored the induced magnetic field and plasma environment and established the global escape rates of $3{\cdot}10^{24}s^{-1}$, $7{\cdot}10^{24}s^{-1}$, $8{\cdot}10^{22}s^{-1}$ for O^+, H^+, and He^+ ions and identified the main acceleration process. For the first time it was shown that the reconnection process takes place in the tail of a non-magnetized body. It was confirmed that the lightning tentatively detected by Pioneer-Venus Orbiter indeed occurs on Venus.

Thermal mapping of the surface in the near-IR spectral “windows” on the night side indicated the presence of recent volcanism on the planet, as does the high and strongly variable SO_2 abundance. Variations in the thermal emissivity of the surface observed by the VIRTIS imaging spectrometer indicated compositional differences in lava flows at three hotspots. These anomalies were interpreted as a lack of surface weathering suggesting the flows to be younger than 2.5 million years indicating that Venus is actively resurfacing. The VMC camera provided evidence of transient bright spots on the surface that are consistent with the extrusion of lava flows that locally cause significantly elevated surface temperatures. The very strong spatial correlation of the transient bright spots with the extremely young Ganiki Chasma, their similarity to locations of rift-associated volcanism on Earth, provide strong evidence of their volcanic origin and suggests that Venus is currently geodynamically active.

Alongside observations of Earth, Mars and Titan, observation of Venus allows the opportunity to study geophysical processes in a wide range of parameter space. Furthermore, Venus can be considered as an archetype of terrestrial exoplanets that emphasizes an important link to the quickly growing field of exoplanets research.

The talk will give an overview of the Venus Express findings including recent results of data analysis, outline outstanding unsolved problems and provide a bridge, via the Akatsuki mission, to the missions to come in 2030s: EnVision, VERITAS and DAVINCI.