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Dynamics and chemistry of Venus' large and complex cloud system : a science case for an in-situ long-term chemical laboratory

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The planet Venus is the closest to the planet Earth both geographically and geometrically, with an average solar distance only 0.3AU smaller than that of Earth and an equatorial radius that is only 5% smaller than Earth's. But the similarities appear to end there. How did the environments of Venus and Earth become so divergent? The answer to this question relies upon an understanding of Venus' origins, the nature of its present atmosphere, and the role that the clouds have played in evolution and current state of Venus.

Venus' clouds are composed of highly concentrated solutions of sulfuric acid and water. The sulfuric acid is produced photochemically from reactions involving water vapor and various sulfur species such as SO_2 in the upper atmosphere around 62 km. The region from 50-60 km altitude is convectively unstable, suggesting that most of the cloud formation here is convectively driven, as are cumulus clouds on Earth but with sulfuric acid taking the place of water as the main condensable species. The clouds of Venus are ubiquitous, play a significant role in the radiative balance of the planet, are used as tracers to probe the atmospheric circulation, and are a key part of a global sulfurohydrological cycle that redistributes key greenhouse gasses such as SO_2 and H_2O. Thus understanding the clouds of Venus holds the key to understanding how Venus itself came to be the world of extremes that it is today.

ESA's Venus Express mission, launched in Nov. 2005, has significantly improved our knowledge about the atmosphere of Venus by providing global long-term remote sensing observations with complete coverage in latitude and local solar time. However major questions remain about key minor species and how they vary throughout the major atmospheric regimes in the upper atmosphere, near the cloud tops where photolysis and condensation processes occur, near the surface where coupling and interchange with the atmosphere occurs, and in the middle atmosphere where they combine through meso-scale convection. In situ sampling of these aerosols represents a key measurement for constraining their properties, and identifying their role in the sulfurohydrological cycle by means of microphysical models of steadily increasing complexity. A probe/lander making a single descent will lack the spatial, temporal and local time coverage to address the coupling of compositional variations with radiative and dynamical properties of the atmosphere at cloud level, requiring a long duration flight.

Establishing a long-term chemical laboratory in the cloud layer which would measure the detailed composition of both gas and liquid phases, and their latitudinal, diurnal and vertical variability using a combination of mass spectrometry, gas chromatography, tunable laser transmission spectrometry, and polar nephelometry would significantly address all of these objectives. It would allow the determination of the size distribution, shape, and real and imaginary refractive indices of the cloud particles, and the measurement of intensity and polarization phase functions. Our target species would include those known to be associated with cloud formation (e.g. H2SO4, SO_3, SO_2, H_2O), as well as species important in stratospheric chemistry (e.g. CO, ClCOx, Ox, HCl, HF) and surface-atmosphere buffering (e.g. CO, OCS, SOx, Ox, H2S).