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Coherent Doppler Lidar for Wind Measurements on Venus

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Since the discovery of the superrotation of the Venus atmosphere from surface to $\sim$ 95 km altitude, the processes supporting it have been a puzzle. Many numerical models are being developed to simulate this superrotation at present, and although the models can re-produce the so called "4-day" wind, the models differ significantly in the details and even the processes producing the superrotation. To understand the superrotation of Venus atmosphere, globally distributed measurements of winds on day and night at multiple levels are needed to estimate accurately the meridional and vertical transport of angular momentum. Currently, cloud tracked winds are the only means of providing global coverage, but they provide details only on day (reflected solar at or just below the cloud tops) or the night side (near infrared, mid-level to near bottom of the cloud layer). However, the presence of strong vertical shear of the zonal flow at these levels makes it difficult to accurately estimate the angular momentum transports and detect the presence of planetary waves from the results as the level of the cloud-tracked winds cannot be accurately determined.

Given the presence of clouds and haze in the upper portion of the Venus atmosphere, it is reasonable to consider a Doppler wind lidar (DWL) for making remote measurements of the 3D winds within the tops of clouds and the overlying haze layer. Assuming an orbit altitude of 250 km and cloud tops at 60km (within the "upper cloud layer"), an initial performance assessment of an orbiting DWL was made using a numerical instrument and atmospheres model developed for both Earth and Mars. The threshold aerosol backscatter for 2-micron was taken to be 1.0*10-6 msr-1. This backscatter value is between 1 and 2 orders of magnitude lower than that expected for clouds with optical depths greater than 2.0. Cloud composition was assumed to be mixture of dust, frozen CO2 and sulfuric acid. Based on the DWL assessment and simulation, it is reasonable to expect vertical profiles of the 3D wind speed with 1km vertical resolution and horizontal spacing of 25 km to several 100 kms depending upon the desired integration times. These profiles would begin somewhere just below the tops of the highest clouds and extend into the overlying haze layer to some TBD height. Getting multiple layers of cloud returns is also possible with no negative impact on velocity measurement accuracy.

With support from the NASA Laser Risk Reduction Program (LRRP) and Instrument Incubator Program (IIP), NASA Langley Research Center has developed a state-of-the-art compact lidar transceiver for a pulsed 2-micron coherent Doppler lidar system for wind measurement in the Earth's atmosphere. The knowledge and expertise for developing coherent Doppler wind lidar technologies and techniques for Earth related mission at NASA LaRC can be leveraged to develop an appropriate system suitable for wind measurement around Venus. The fiber laser based lidar system of high efficiency and smaller size can be easily developed and technology readiness level can be advanced to meet the requirements for an orbiting DWL system for Venus.