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Simulation of Martian Cloud Formation Associated With Topography by the Planetary Weather Research and Forecasting Model

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Martian clouds are often seen over volcanoes, Valles Marineris and troughs in Polar Regions. Clouds form above Olympus Mons (18N, 227E) and the three Tarsis volcanoes from an areocentric solar longitude (L_s) of 0 to 220 deg. with a peak near L_s=100 deg, while cloud activity above Alba Patera (40N, 256E) has two peaks at L_s = 60 and 140 deg. with a minimum near L_s=100 deg. The latter is anit-correlated with the development of the equatorial cloud belt, which indicates that the global transportation of water affects on the cloud activity.

The purpose of this research is to study the mechanism of cloud formation associated with topography. Terrains affect greatly the wind system and the atmospheric temperature. We use the Planetary Weather Research and Forecasting (planetWRF) model for this study. It has been modified at Caltech from the terrestrial mesoscale WRF model developed mainly by the National Center for Atmospheric Research (NCAR). It can simulate, for example, the diurnal / seasonal change of wind direction and temperature profile as global or mesoscale models with high spatial resolution. We have installed two microphysics schemes into PlanetWRF. The first includes heterogeneous nucleation, growth and sublimation of water ice particles, sedimentation due to gravity, and transfer due to advection and eddy diffusion. Particles are allowed to precipitate to the surface and form frost. The second is a much faster, simpler parameterization in which the parameter choices are based on the results of the first method. Using the latter scheme decreases the computational time greatly.

We will show the results of cloud formation with the complete microphysics scehme in mesoscale simulations. For examples, a simulation in a region of Olympus Mons (20 km high) at L_s = 90 deg. shows the following. Upslope wind develops along the slops in the morning. Air parcels are transferred by wind from the foot to the summit and the temperature above the summit becomes cold. Cloud forms at 10:00 LST at an altitude of 30 km and water ice particles grow in day time supported by strong vertical wind and cold temperature. The effective particle radius can be 30 micron, however the particles fallen sublimate before reaching the surface due to warm temperature between the summit and the cloud active region. The increase in water vapor due to sublimation is seen in this atmospheric layer. In the evening, atmospheric activity settles down and the temperature above the summit becomes the same as the surrounding air. After large particles fall and sublimate, only small particles with an effective particle radius of 2-3 micron remain. A thin cloud stays at night. On the other hand, the cloud formation over Alba Patera is active in the afternoon and at night in a simulation starting from L_s=60 deg. The slope of Alba Patera, 8 km high and 1600 km across, is much gentler than that of Olympus Mons and upslope wind becomes strong enough to lead cloud formation in the afternoon. Although the cloud once disappears in the late evening, the temperature at 3:00 LST becomes cold enough to form cloud at an altitude of 20 km again, which remains until the next morning.