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The Martian meteorology: overview of dust storm science

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Martian atmospheric dust has large influence on the thermal and circulation structure of the Martian atmosphere. Since Mariner 9 experiment, various atmospheric phenomena associated with dust, such as the global dust storm and the dust devil, have been observed by many spacecrafts. In this presentation, the role of the dust in the Martian atmosphere is reviewed on the basis of observation resluts and numerical studies of Martian atmosphere. A main issue is the global dust storm by which the whole planet is covered with dust.

1. Overview of observation results

The ranges of atmospheric temperature and pressure in Mars correspond to that of the Earth's upper stratosphere and mesosphere. The surface pressure has seasonal change from 5 to 10 hPa, since condensation and sublimation of major atmospheric component, CO2, occur in winter and summer poler region, respectively. The vertical gradient of atmospheric temperature observed by spacecraft is frequently smaller than adiabatic lapse rate. It is caused by radiative heating associated with dust. The meridional distribution of atmospheric temperature is obtained by remote sensing observation of spacecraft. The meridional distribution of zonal wind estimated by using thermal wind relation shows existence of easterly in summer hemisphere and westerly in winter hemisphere.

The amount of water vapor in the Martian atmosphere is so small that the condensation heating of water vapor has almost no effect on circulation structure of the Martian atmosphere.

The visible optical depth of dust is usually about 0.3. It increases up to about 5 when the dust storm occurs. The dust storm is classified into three type by its horizontal scale: the local dust storm with horizontal scale smaller than 2000 km, the regional dust storm which has horizontal extent over 2000 km but do not encircle the planet, and the global dust storm which covers much of one or both hemispheres. The global dust storm observed by MGS last year is the largest one. It started at Hellas basin in southern hemisphere and extend to the whole planet. The thermal and dynamical structure of atmosphere is affected by radiative heating of dust during the global dust storm. The poler warming observed during the global dust storm is caused by increasing of adiabatic warming associated with downwelling of the meridonal circulation.

2. Numerical modeling of Martian atmosphere and the global dust storm

Many numerical studies have been performed to understand observed artian atmospheric phenomena. Fundamental understanding about atmospheric mean structure is obtained by studies with 1D radiative-convective model from 1960's to 1970's. Mars General circulation model (MGCM) has been developed by NASA since 1964, and its standard model is released at 1990. Current MGCM can reproduce the characteristics of observed circulation structure. By using MGS meteorological date, the numerical weather prediction of Mars becomes a possible gole of the Martian meteorology. The reason why MGCM succeeds is that many experiences and techniques of Earth GCM can be available without sever modification.

However, the onset of the global dust storm can not be simulated self-consistently by using current MGCM. In the case of dust-free or small amount of dust, the surface stress calculated by large scale wind in MGCM is not sufficient to raise dust from the surface. Therefore, the transition from dust-free Mars to dusty Mars can not be simulated by using MGCM naturally. It is suggested that the surface stress could be supplemented by small-scale wind fluctuations which are not represented in MGCM contribute to dust injection into the atmosphere. Numerical study with meso-scale model, which can represent the small small-scale wind fluctuations, is performed recently. By using 1D, meso-scale, and global numerical models, the role of the dust in the Martian atmosphere will be understood from various viewpoints.