THE CLOUDS OF MARS

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PRE-MARINER FINDINGS

Three main cloud types have been distinguished in the thin,dry,cold Martian atmosphere: white, blue and yellow clouds, so named for the colours which they predominantly reflect.

White Clouds:

White clouds vary considerably in thickness, brilliance and extent. They can be subdivided into three categories:

(1) Dense, brilliant, white clouds frequently observed as large systems in motion in the equatorial and temperate zones, or as thick, white shrouds over the winter pole lasting several months. In the midlatitudes, they last for days wor weeks, change shape irregularly, and, at times, extend conspicuously over the terminator.

(2) Thin, white mists detected polarimetrically as extensions of the thick, white clouds, or as mists of brief duration occurring with sudden temperature drops. Thus, mists formed during the night appear on the sunrise limb, but are quickly dissipated. Thin mists of this kind have also been detected migrating in spring from pole to pole.

(3) Orographic clouds appearing repeatedly over what are presumed to be high altitude surface areas such as the Nix Olympica and Candor ranges.

Dollfus has demonstrated that the polarization of all Martian clouds closely resembles those of the terrestrial ice-crystal clouds or fogs. He has concluded that the white clouds on Mars are analogous to the terrestrial cirrus clouds. (Refs. 1,2 & 3)

Blue Clouds:

The distinction between blue and white clouds is not always clear.The blue clouds frequently appear along with white clouds and mists, but are probably at higher altitudes. Strictly speaking, blue clouds are those which reflect blue and ultraviolet light only. Generally, however, classification is a question of degree.

Blue clouds appear at the winter pole and are reduced to mists in the summer. Blue mists also appear quite commonly over the terminator at sunrise, and sunset in the equatorial belt. Finally, orographic blue clouds are evident periodically over certain preferred areas. For example, a large W-shaped cloudn formed repeatedly over the Thersis region in 1926, 1954 and 1958. Blue clouds frequently appear as bumps or distortions of the blue disc of Mars (ie: when Mars is viewed through a blue filter). When associated with white cloud systems, the blue seems to dominate. These facts have led to the conclusion that blue clouds are relatively high in the Martian atmosphere. Wilson (refs.4 & 5) estimates their elevations as 15 and 25 kilometers, with a possible maximum of 100 kilometers. By comparison with terrestrial noctilucent clouds, he maintained that blue clouds are simply condensed blue haze. Estimates of cloud-

particle size range from 0.1 micron by Goody (ref.6) for ice-crystals, to 2 to 2.5 microns by Dollfus for fine water droplets.

Yellow Clouds:

Yellow clouds, generally explained as Martian duststorms, are relatively infrequent but have shown a great deal of variability. Subdivision by size or extent results in three broad categories.

(1) Major formations are generally opaque, mobile and enduring. They were observed on a planetary scale in 1924, 1956 and 1971.

(2) Smaller formations in the form of localized yellow clouds are more frequent. Their properties are similar to those of major formations, but they are less intense. (Ref. 7)

(3) Faint yellow veils which are detected photometrically or polarimetrically are believed to be the "tail end" of duststorms.

A dusty nature for the yellow clouds is generally accepted for the following reasons:

(1) Polarimetry indicates that the bright areas of Mars are composed of a powdery material.

(2) The cloud motions suggest the likelihood of strong local winds capable of lifting and carrying dust to great heights.

(3) The low gravity on Mars allows a long settling time.

(4) The rapid increase of polarization in the yellow veils going toward the limbs can be explained only by particles greater than molecules.

Yellow clouds, and particularly major formations, have been observed most frequently during perihelic or near-perihelic oppositions. (Ref.8)

The polarization curve of an opaque yellow cloud most closely resembles that of tobacco smoke and not that of ordinary Earth dust! The negative polarization led Dollfus (Ref.2) to believe that they are composed of minute highly absorbent particles. Earth dust is primarily transparent quartz sand and polarizes in the positive sense. Dollfus has obtained from 2 to 5 microns as an estimate of the yellow-cloud particle diameters. However, this size is largely underestimated, according to Ryan.(Ref.9)

POST-MARINER FINDINGS:

Most of the clouds observed by Mariner IX could be divided into two general classes. From 55° up to 70° north latitude, clouds were diffuse and structureless. They appeared to be close to the surface and were not thick enough to obscure scattered patches of surface frost. Infrared radiometer and spectrometer data showed that the temperatures in this region were close to the 146°Kelvin frost point of carbon dioxide, and these clouds were inferred to be a ground-fog or thick haze of carbon dioxide ice particles. Between 45° and 60°, depending on day-to-day variations, spectacular cloud waves were usually observed. Two types of waves were seen: relatively long waves with spacings of 30 to 40 kilometers between adjacent crests, and shorter wavelets spaced about 5 kilometers apart. The long wave clouds were usually between 7 and 15 kilometers high, and 2 or 3 kilometers thick; they were closely associated with large topographical obstacles and were obviously produced by deflection of the airflow over the obstacle. Waves of this type are common in the Earth's atmosphere downwind from large mountain ranges such as the Sierras or the Andes. They are known as lee waves, and are formed as air, forced to rise

over a range becomes cooler and therefore denser than its surroundings.

The small cloud wavelets that were observed usually appeared to be much closer to the surface. They may also have been formed by flow over topography, but there is no obvious relationship between these waves and surface features, and it is more likely that they are formed by overturning air at the interface between a slow-moving layer of air and a relatively rapidly-moving higher one. Temperatures were high enough to show that both the long wave clouds and the shorter cloud wavelets should have been made of water ice rather than carbon dioxide ice, and the infrared data showed that water ice was present in the region.

Day-to-day variations in northern clouds revealed fronts and large-scale storm systems like those that occur at middle and high latitudes on Earth. Clouds of carbon dioxide ice particles moving behind cold fronts showed marked curvature in the cyclonic (counterclockwise) sense, indicating the presence of a large low-pressure area in the cold air, perhaps 2000 to 4000 kilometers in diameter.

Not all of the condensation clouds observed were easily interpretable in terms of familiar terrestrial processes. As the northern summer progressed, a different type of cloud was seen to develop each afternoon over the west slopes of Olympus Mons and the three great calderas of the Tharsis dome. Clouds have often been seen in this region by astronomers but the reason for their regular seasonal and diurnal occurrence remains a mystery. Infrared data showed the clouds to be made of ice crystals, and their seasonal appearance may coincide with the period when the water vapour released from the northern polar cap reaches its maximum concentration in the atmosphere. The diurnal recurrence may be due to the daily heating and rising of this moist air up the slopes of the volcanoes. There may also be more water vapour in the atmosphere near the calderas than elsewhere.

Even more puzzling were some of the clouds observed near the retreating north polar cap during the summer. These long clouds seen streaming off the cap towards the southwest may have been due to water vapour subliming from the cap and condensing in the atmosphere. They were quite unlike anything known in the Earth's atmosphere.

Material obtained from NASA Publications SP 337 and SP 3030.

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